



In-Training Examination
for Radiation Oncology Residents

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1. As recommended by the ASTRO evidence-based clinical practice guidelines for palliative thoracic therapy:
 - A. IMRT techniques have demonstrated improved symptom control.
 - B. Higher dose-fractionations (30 Gy/10 fractions or greater) improve total symptom score and survival at cost of increased side effects.
 - C. Addition of chemotherapy concomitantly with palliative radiation is recommended for improved symptom control.
 - D. Endobronchial brachytherapy is an effective approach for initial palliation.

Key: B

Citations: Lancet Oncology Mulvenna P. 2016 Oct 22. 2016;17(10):1004-14.

Rationale: The ASTRO evidence-based clinical practice guidelines summarize following recommendations regarding palliative thoracic RT: The clinical trial evidence has demonstrated that higher dose radiation treatment fractionations (30 Gy /10-fraction equivalent or greater) are associated with improvements in total symptom score and survival (but at the cost of some increased side effects, such as radiation esophagitis), primarily in patients with good performance status. Various shorter fractionation schedules (eg, 20 Gy in 5 fractions, 17 Gy in 2 fractions, and 10 Gy in 1 fraction) also provide good symptomatic relief and can be used for patients requesting shorter total treatment courses and also for patients with poor performance status. Overall, studies to date have suggested that the benefit/ risk ratio does not support the addition of chemotherapy concomitantly with radiation for the palliation of LC, primarily because of concerns regarding toxicity and no clear evidence that symptom palliation is improved. The role of advanced techniques such as IMRT have not been clearly defined. No defined role for endobronchial brachytherapy (EBB) for the routine initial palliative treatment of chest disease has been demonstrated; however, it is an option for the palliation of endobronchial lesions causing obstructive symptomatology in the EBRT failure scenario or in locally advanced nonmetastatic cancer patients with endobronchial disease who require lung re-expansion before or in conjunction with radical RT.

2. In the GRECCAR-2 randomized trial of patients with T2-3N0-1 low lying rectal cancer to local excision versus total mesorectal excision (TME) in patients with a good clinical response after CRT. What was the rate of lymph node involvement at the time of surgery?
- A. <10%
 - B. 11-20%
 - C. 21-30%
 - D. 31-40%

Key: A

Citations: Organ preservation for rectal cancer (GRECCAR 2): a prospective, randomised, open-label, multicentre, phase 3 trial Rullier E, et al.2017, Jul 29390(10093): 469-479.

Rationale: This French, multicenter, Phase III randomized trial included patients with T2-3N0-1 low lying rectal cancer (<8 cm from the anal verge) not involving the anal sphincter, <4 cm in diameter. There were no significant differences between local excision and TME with regard to operative death, tumor recurrence, disease-free survival, overall survival, and major morbidity. Local recurrences occurred in 5-6% of all patients with an 89% (LE) and 95% (TME) overall survival rate at 3 years. In sum, there was no superiority of local excision due to the high number of completion TMEs performed, and TMEs increased morbidity and side effects at 2 years. But the large number of nodal responses suggests that completion TME was not often necessary; only 8% of lymph nodes occurred in small, irradiated tumors. Given this small rate of lymph node positivity, the authors thought that completion surgeries could be limited to less than 10% of patients with ypT2/N1 and ypT3 tumors.

3. What is the target of Atezolizumab, recently approved for locally advanced or metastatic bladder cancer?
- A. CTLA-4
 - B. PD-1
 - C. PD-L1
 - D. HER-2

Key: C

Citations: Atezolizumab in patients with locally advanced and metastatic urothelial carcinoma who have progressed following treatment with platinum-based chemotherapy: a single-arm, multicentre, phase 2 trial. Rosenberg JE, Hoffman-Censits J, Powles T, et al. 2018; 387:1909-1920. Lancet.

4. The pterygopalatine fossa is an important route of cancer spread in the head and neck and skull base. It abuts which anatomic structures as seen on axial CT-images?
- A. Medial and lateral pterygoid muscles
 - B. Posterior maxillary sinus and pterygoid plates
 - C. Foramen rotundum and Meckel's cave
 - D. Hard palate and maxillary incisors

Key: B

Citations: Osseous anatomy of the pterygopalatine fossa. Daniels et al. 1998. AJNR Am J Neuroradiol. 1423-1432; 19(8).

Rationale: The boundaries of the pterygopalatine fossa can be seen on axial CT studies and is bounded by the pterygoid plates posteriorly and anteriorly by the maxillary bone.

5. Which patient would be considered “suitable” for consideration of APBI according to the updated ASTRO consensus statement?
- A. 42 yr old, pT1N0 ER positive ILC, 3 mm margins
 - B. 52 yr old, pT1N0 ER positive IDC, 2 mm margins
 - C. 62 yr old, pT1N0, ER negative IDC, 3 mm margins
 - D. 62 yr old, pTis, 1.5 cm, low grade, 2 mm margins

Key: B

Citations: Correa et al. PRO, 2017:7, p. 73-79.

Rationale: According to the updated ASTRO consensus statement on APBI, suitability criteria include: Age \geq 50 yrs; T1 disease with margins of at least 2mm; for DCIS—screen detected, low to intermediate grade, size \leq 2.5 cm, margins of at least 3 mm. Cautionary criteria: age 40-49 yrs; patients \geq 50 yrs with the following: size 2-3 cm, T2, margins $<$ 2mm for invasive disease, limited or focal LVSI, ER negative, invasive lobular disease, EIC \leq 3 cm, DCIS $<$ 3 cm not meeting the requirements for suitable group. Patient age $<$ 40 yrs, positive margins, and DCIS $>$ 3cm are considered unsuitable.

6. What action is required by the Nuclear Regulatory Commission (NRC) to confirm that no sources remain in the patient after treatment is completed?
- A. Pre-treatment radiation survey of the patient
 - B. Post-treatment radiation survey of the patient
 - C. Pre-treatment time out of patient identity
 - D. Post-treatment time out of patient identity

Key: B

Citations: Practical Radiation Oncology, Physics, Sonja Dieterich, 2016, 115, Elsevier, 1st edition.

Rationale: The NRC requires that a post-treatment radiation survey of the patient be performed to confirm that sources are not inadvertently left in the patient that could result in an overexposure to the patient and public.

7. For a right-sided whole breast treatment, the right lung contour erroneously includes both left and right lung volumes, what is the effect on the right lung mean dose reported in the treatment plan?
- A. Erroneously higher
 - B. Erroneously lower
 - C. No effect
 - D. Depends on delivery technique

Key: B

Citations: Practical Radiation Oncology, Physics, Sonja Dieterich, 2016, 199, Elsevier, 1st edition.

Rationale: The volume of the contour receiving little to no dose in a breast plan would be erroneously increased. This would therefore result in an incorrectly lower mean dose to the right lung.

8. What was the maximum point dose allowed to the spinal cord in NRG Oncology/RTOG 0813 clinical trial investigating a 5 fraction course of stereotactic radiation for the treatment of centrally located early stage lung cancers?
- A. 20 Gy
 - B. 30 Gy
 - C. 40 Gy
 - D. 50 Gy

Key: B

Citations: International Journal of Radiation Oncology Biology Physics. Bezjak, A. October 1, 2016. Supplement page s 896 (2).

References: The maximum point dose allowed to the spinal cord is 6 Gy per fraction (total 30 Gy). Other spinal cord constraints were $D<0.25\text{cc}=22.5$ Gy and $D<0.5\text{cc}=13.5$ Gy. Max point dose allowed to the brachial plexus and skin were 32 Gy. Max point dose allowed to the esophagus, heart/pericardium, the non-adjacent walls of the great vessels, trachea and ipsilateral bronchus were 105% of prescription.

9. What molecular marker provides prognostic information for grade II astrocytomas?
- A. INI-1
 - B. WNT
 - C. IDH
 - D. Her2

Key: C

Citations: Comprehensive, Integrative Genomic Analysis of Diffuse Lower-Grade Gliomas. Cancer Genome Atlas Research Network, Brat DJ, Verhaak RG, Aldape KD et al. 2015 Jun 25. 372(26):2481-98. N Engl J Med. Glioma Groups Based on 1p/19q, IDH, and TERT Promoter Mutations in Tumors. Eckel-Passow JE, Lachance DH, et al. 2015 Jun 25. 372(26):2499-508. N Engl J Med.

Rationale: Gliomas are being classified by molecular status in view of data identifying molecular markers such as isocitrate dehydrogenase (IDH), to be predictive of clinical outcome. IDH mutation is associated with more favorable outcomes.

10. What is recommended for a pT1b1N0M0 squamous cell carcinoma of the cervix with negative margins, invasion of the deep third of the cervical stroma, and extensive LVSI?
- A. EBRT
 - B. Vaginal brachytherapy
 - C. Chemotherapy
 - D. ChemoRT

Key: A

Citation: Int J Radiat Oncol Biol Phys. Rotman M. 2006, 65(1):169-76.

Rationale: Patients with intermediate risk for recurrence after radical hysterectomy (for example, those at least two of the following risk factors: >middle or deep stromal invasion, + LVSI, and tumor diameter >4cm) benefit from postoperative external beam radiotherapy. The GOG 92 study randomized 237 such patients to observation vs. pelvic radiotherapy. Radiotherapy was associated with a statistically significant reduction in any recurrence and with a trend towards improved overall survival. A randomized study of chemotherapy is still ongoing. Most recurrences in untreated patients are pelvic so vaginal brachytherapy alone is insufficient.

11. On the UK START B Trial for early breast cancer, 50 Gy in 25 fractions was compared to 40 Gy in 15 fractions. Which endpoint was superior on the 40 Gy arm?
- A. Breast edema and shrinkage
 - B. Loco-regional recurrence
 - C. Shoulder stiffness
 - D. Arm lymphedema

Key: A

Citations: Haviland J, Lancet Oncol, 2013, 14(11):1086-1094.

Rationale: The 2018 ASTRO guidelines on whole breast irradiation recommend the routine use of hypofractionation when a nodal field is not used. This recommendation is supported by data from 5 randomized trials demonstrating equivalent loco-regional control and survival. Additionally, in the START B trial, the 40Gy regimen yielded superior cosmetic outcomes of breast shrinkage, edema, and telangiectasia. There was no difference in shoulder stiffness or arm lymphedema.

12. The sensitivity of a screening test is:
- A. % of subjects without disease who are classified as not having disease.
 - B. % of subjects with disease who are classified as having disease.
 - C. % of subjects without disease who are classified as having disease.
 - D. % of subjects with disease who are classified as not having disease.

Key: B

Citations: Judith S. Mausner, Shira Kramer, Mausner and Bahn Epidemiology: An Introductory Text, 1985, Chapter 11, W. B. Saunders Company, 2nd edition.

Rationale: Screening refers to the application of test to people who as yet have no symptoms of a particular disease. It is classified as having a positive (disease likely) or negative (disease unlikely) finding. Diagnostic tests tell whether or not a subject actually has the disease. The performance of a screen test is considered by the sensitivity and specificity. The sensitivity is the percentage of subjects with disease who are classified as having disease and the specificity is the percentage of subjects without disease who are classified as not having disease. Those subjects with the disease should all be classified as having disease, and those subjects without the disease should be classified as not having disease. Therefore, a highly sensitive and specific test is preferred.

13. A healthy 50-year-old woman with no family history of cancer has a core needle biopsy showing classic LCIS. Imaging is concordant. What would be recommended as a next step in management?
- A. Adjuvant radiation
 - B. Counseling on risk reducing endocrine therapy
 - C. Surgical excision with > 2mm margins
 - D. Mastectomy

Key: B

Citations: NCCN Breast Cancer Guidelines, Version 1.2018.

NCCN Breast Cancer Screening and Diagnosis Guidelines, Version 2.2018.

NCCN Breast Cancer Risk Reduction Guidelines, Version 2.2018.

Rationale: LCIS is not staged nor treated as DCIS or invasive breast cancer. Patients with concordant imaging and classic LCIS do not require excision. Surgical excision is usually recommended for pleomorphic LCIS and for LCIS on biopsy and non-concordant imaging to exclude underlying invasive disease or DCIS. Patients with LCIS should be counselled on risk reducing therapies and advised on surveillance with annual diagnostic mammography.

14. A study is planned to test whether the treatment decreases AST level. The patients had a mean AST of 30 U/L at the baseline. After the treatment their mean AST decreased to 20 U/L. The standard deviation for the AST difference is 2.5 U/L. Which of the following describes the analysis?
- A. The null hypothesis is that the treatment has no effect on the AST level decrease. This is a two-tailed test.
 - B. The null hypothesis is that the treatment decreases the AST level. This is a two-tailed test.
 - C. The null hypothesis is that the treatment has no effect on the AST level decrease. This is a one-tailed test.
 - D. The null hypothesis is that the treatment decreases the AST level. This is a one-tailed test.

Key: C

Citations: Biostatistics: A methodology for the health sciences, Lloyd D. Fisher and Gerald van Belle, Wiley-Interscience, 1993.

Rationale: The null hypothesis $H_0: d=0$; the alternative hypothesis $H_1: d<0$, where d denotes the AST difference between the baseline and end of study. This is a left-tailed test since it emphasizes the “decrease” instead of any difference.

15. DNA double-strand breaks are repaired by which mechanism?

- A. Mismatch Repair
- B. Base Excision Repair
- C. Nucleotide Excision Repair
- D. Nonhomologous End-Joining

Key: D

Citations: Radiation Biology for the Radiologist Eric Hall and Amato Giaccia 2012. 18 Lippincott Williams Wilkins 7th edition.

Rationale: Nonhomologous end-joining (NHEJ) and Homologous Recombination (HR) are the two primary processes that repair DNA double-strand breaks in eukaryotes. In “more complex” eukaryotes, like humans, NHEJ primarily occurs in the G1 phase of the cell cycle, and HR is responsible primarily for repair in the late S/G2 phase of the cell cycle.

16. Which pathologic feature of endometrial cancer would prompt inclusion of the presacral lymphatics in the CTV for adjuvant RT?

- A. Extensive LVI
- B. Deep myometrial invasion
- C. Uterine fundal involvement
- D. Cervical stromal involvement

Key: D

Citations: Uterine Neoplasms. NCCN Guidelines in Oncology 5/25/18. National Comprehensive Cancer Network 1-103.

References: Per NCCN guidelines, pelvic radiotherapy should target the gross disease (if present), the lower common iliacs, external iliacs, internal iliacs, parametria, upper vagina/para-vaginal tissue, and presacral lymph nodes (in patients with cervical involvement).

17. Protons are preferred for therapeutic treatments of some anatomical sites. What is the principal justification for this?
- A. DNA damage is irreparable
 - B. Hypoxic cells are sensitive to photons
 - C. Limit dose to normal tissue
 - D. The OER for protons is above 4

Key: C

Citations: Radiobiology for the Radiologist, Seventh ed. Hall and Giaccia, p423.

Rationale: Both RBE is similar and LET is similar except for the end of the track. The OER is also similar to X rays, so cell kill in hypoxic regions wouldn't be expected to be greater (except at the track end). The spread out Bragg peak can be utilized to treat the tumor and to limit dose to surrounding normal tissues.

18. Which is NOT a recognized hallmark of cancer?
- A. Self-sufficiency in growth signals
 - B. Activation of apoptosis
 - C. Evading the immune system
 - D. Limitless replicative potential

Key: B

Citations: Cell, Hanahan, March, 2011, 144(5) 646-674.

Rationale: The original hallmarks of cancer were (1) self-sufficiency in growth signals; (2) insensitivity to anti-growth signals; (3) evading apoptosis; (4) limitless replicative potential; (5) sustained angiogenesis; (6) tissue invasion and metastasis. Four new hallmarks were added in 2011 including (1) abnormal metabolic pathways, (2) evading the immune system, (3) genome instability, and (4) inflammation. Tumors generally resist programmed cell death by evading apoptosis rather than activating apoptosis.

19. For completely resected (R0) Masaoka stage I-III thymoma, which stage(s) may have the LEAST likelihood of an overall survival benefit from post-operative radiation?
- A. Stage I
 - B. Stage II
 - C. Stage III
 - D. No OS benefit for any stage

Key: A

Citations: Journal of Thoracic Oncology. Andreas Rimner et al. June 11, 2016; 1785-1792.

Rationale: In an analysis of 1263 patients (Rimner et al.) with R0 stage II or stage III thymoma identified in a large database of the International Thymic Malignancy Interest Group, 5- and 10-year OS rates for surgery + PORT were 95% and 86%, respectively, compared with 90% and 79% for surgery alone ($p = 0.002$). This OS benefit remained significant when patients with stage II ($p = 0.02$) and stage III thymoma ($p = 0.0005$) were analyzed separately. On multivariate analysis, PORT was significantly associated with improved OS (HR of 0.58 (95% CI: 0.34–0.97, $p=0.037$)). There is some controversy regarding the use of PORT for stage II disease with mixed results seen in different series.

20. In the RTOG 9704 adjuvant pancreatic cancer trial of chemoRT plus gemcitabine or 5-FU, what percentage of patients had the first site of relapse at a distant site (average between both arms)?
- A. 36
 - B. 52
 - C. 73
 - D. 94

Key: C

Citations: Ann Surg Oncol 2011; 18:1319–1326.

Rationale: This study was an adjuvant trial comparing 5FU plus radiotherapy with additional 5FU systemic therapy vs the same chemoradiation but with gemcitabine as systemic therapy. Patients received a month of chemotherapy, then chemoradiation, then another 3 months of chemotherapy. Overall, there was no significant difference in OS between the two arms. Local recurrence rates on this adjuvant study with a chemoradiation backbone were low (28% first site of relapse). The first site of relapse was distant in 73% of the patients, overall. The authors recommended completing additional systemic therapy before initiating chemoradiation, and this has informed the design of RTOG 0848.

21. What is the MOST appropriate radiation dose and volume for treatment of a 6-year-old girl with a localized anaplastic supratentorial ependymoma status post gross total resection?
- A. No radiation
 - B. 59.4 Gy to the tumor bed
 - C. 23.4 Gy to the craniospinal axis with a tumor bed boost to 54 Gy
 - D. 36 Gy to the craniospinal axis with a tumor bed boost to 54 Gy

Key: B

Citations: Landau, et al. IJROBP, 2013, Mar 15; 85(4): p193-9.

Rationale: Observation is allowed on the COG trial ACNS0831 for a microscopically gross totally resected classic histology, supratentorial ependymoma. For localized ependymoma, CSI is not appropriate.

22. The binding energy per nucleon declines for large atomic nuclei, because:
- A. high atomic number nuclei have more neutrons than protons.
 - B. the Coulomb repulsion has a long range and the strong nuclear force has a short range.
 - C. the weak nuclear force is dominated by the strong nuclear force for large nuclei.
 - D. large nuclei are less likely to have an even number of protons and an even number of neutrons.

Key: B

Citations: The Physics and Technology of Radiation Therapy, McDermott Orton, 2010, 3-7, Medical Physics Publishing, 1st edition.

Rationale: The binding energy per nucleon declines for large atomic nuclei because the range of the strong nuclear force is short and for large nuclei the destabilizing long-range Coulomb repulsion becomes more dominant.

23. Which protein leads to the rapid degradation of HIF-1 α by proteasomal degradation under normal oxygen conditions?
- A. PI3K
 - B. Von Hippel Lindau (VHL)
 - C. HIF-1 β
 - D. Carbonic anhydrase 9 (CA9)

Key: B

Citations: Molecular oncology. Rademakers et al. 2008, 41-53.
Nature reviews Cancer. Bristow and Hill. 2008; 180-192.

Rationale: Under normoxic conditions two inhibitory pathways of HIF-1 α are essential. Prolyl hydroxylases (PHDs) hydroxylate proline sites in the oxygen-dependent degradation domain (ODD) of the HIF-1 α protein. This enables binding of the von Hippel Lindau protein (VHL), which leads to the proteasomal degradation of HIF-1 α . Under hypoxic conditions hydroxylation does not occur, leading to accumulation of HIF-1 α .

24. When planning an IMRT treatment, which of the following structures helps quantify dose to an organ at risk (OAR) influenced by inter- and intra-fraction motion?
- A. PTV
 - B. ITV
 - C. PRV
 - D. OAR

Key: C

Citations: Prescribing, Recording and Reporting Intensity-Modulated Photon-beam Therapy. ICRU Report 83, 2010, ICRU.

Rationale: The planning organ at risk volume (PRV) is used to account for internal organ motion and set-up uncertainties around organs at risk (OAR) in radiotherapy.

25. Classic radiation induced liver disease (RILD) includes all of the following EXCEPT:

- A. Elevated alkaline phosphatase (>2 times the upper limit of normal)
- B. Occlusion and obliteration of the central veins of the hepatic lobules
- C. Anicteric hepatomegaly and ascites
- D. Elevation of liver transaminases (>5 times the upper limit of the normal range)

Key: D

Citations: Pan et al., 2010. Radiation-Associated Liver Injury. *Int. J. Radiation Oncology Biol. Phys.* S94-100.
Dawson et al., 2002. Analysis of radiation-induced liver disease using the Lyman NTCP model. *Int. J. Radiation Oncology Biol. Phys.* 810-821.

Rationale: Classically, RILD is defined by veno occlusive disease, characterized by areas of marked venous congestion in the central portion of the hepatic lobules. Alkaline phosphatase is often elevated, couple with non-malignant ascites. Non-classic RILD, typically occurring between 1 week and 3 months after therapy, involves elevated liver transaminases more than five times the upper limit of normal or CTCAE grade 4 levels in patients with baseline values more than 5 times the upper limit of normal within 3 months after completion of RT, or a decline in liver function (measured by a worsening of Child-Pugh score by 2 or more), in the absence of classic RILD.

26. For low LET radiations, asymmetrical exchange-type chromosome aberrations (such as dicentric or ring) lead to a loss of reproductive integrity. The effect of irradiation of induction of aberrations and survival can be approximated by the two-component linear quadratic model. At low doses, what does the linear term in the linear quadratic model describe?
- A. Single directly induced DNA double-strand break
 - B. Two DNA ssbs that are sufficiently proximate to effectively result in a DNA dsb
 - C. Interaction of sublethal pairs that form from two independent electron tracks
 - D. The interaction of sublethal pairs that form from a single electron track

Key: A & D **NOTE:** This item was double-keyed for scoring purposes upon post-exam statistical item analysis.

Citations: Curr Top Radiat Res Q, 1972, 8:85-159.

Rationale: The linear-quadratic (alpha-beta) survival model describes cell surviving fraction (SF) as $SF = e^{-(\alpha D + \beta D^2)}$; where D is dose. This is based on Kellerer and Rossi's Theory of Dual Radiation Action (TDRA). This theory postulates that a cell has certain sensitive sites that can be damaged by radiation to form sublesions. Sublesions cannot by themselves kill a cell, but must interact pairwise with other sublesions to produce lethal lesions that are capable of cell killing. The closer (in time and space) sublesions are to one another; the more likely they are to interact. These interactions can occur in two ways (hence the Dual in TDRA). The sublesion pairs that interact can be produced by a single charged particle track (intratrack lethal lesions) or by two independent charged particle tracks (intertrack lethal lesions). Lethal lesion formation via intratrack action is proportional to dose (αD) while intertrack lethal lesion formation is proportional to the square of the dose (βD^2). The average yield of lethal lesions per cell is the sum of lesions produced by these two processes ($YL = \alpha D + \beta D^2$). For a cell to survive it cannot contain a lethal lesion. This can be calculated from the mean YL using Poisson statistics, where the probability of zero lethal lesions is: $P_0 = e^{-\lambda}$, substituting YL for λ , we end up with: $SF = P_0 = e^{-(YL)} = e^{-(\alpha D + \beta D^2)}$.

27. Which is a KEY difference between breast cancer in women versus men?

- A. Use of mammography as initial imaging test
- B. Use of sentinel node biopsy for axillary staging
- C. Use of the TMN staging system
- D. Use of single agent aromatase inhibitors in the adjuvant setting

Key: D

Citations: Giordano, SH. NEJM. 2018; 378:24; p 2311-20.

Rationale: Approximately 1% of all breast cancers occur in men. BRCA mutations are the most well-established risk factors for breast cancer in men; men with breast cancer should be referred for genetic counselling. The ACR recommends mammography as the initial diagnostic test for men over 25 yrs of age with questionable findings on physical examination (ultrasound recommended as initial imaging test for men < 25 yrs of age or for inconclusive imaging in older men). Sentinel node biopsy is felt to be feasible and accurate in men with breast cancer. Breast cancer staging is the same in men and women. It is not standard to use of single agent aromatase inhibitor in the adjuvant setting for men with breast cancer. The standard endocrine therapy in men is tamoxifen. Efficacy of aromatase inhibitors may be lower in men due to incomplete estradiol suppression from feedback loops.

28. Recent prospective randomized trials for locally advanced prostate cancer suggest that ALL of the following approaches have resulted in improved outcomes EXCEPT:

- A. Surgery followed by early EBRT.
- B. Brachytherapy in combination with EBRT and ADT.
- C. Combined ADT, chemotherapy and immunotherapy.
- D. Dose escalated EBRT with ADT.

Key: C

Citations: ACR Appropriateness Criteria for locally advanced high risk prostate cancer, McLaughlin, PW et al, AJCO, 40: 1-10, 2017

29. Chest radiographs for 500 children were evaluated by two independent radiologists. What method should be used to measure the degree of reliability between these two radiologists?
- A. McNemar's test
 - B. Chi-square test
 - C. One-way analysis of variance
 - D. Kappa coefficient

Key: D

Citations: Biostatistics: A methodology for the health sciences, Lloyd D. Fisher and Gerald van Belle, Wiley-Interscience, 1993.

Rationale: The Kappa coefficient is a widely used statistic for measuring the degree of reliability between different and independent raters. It compares the agreement against that which might be expected by chance. The Kappa coefficient ranges from 1 (perfect agreement) to -1 (complete disagreement). Here is one possible interpretation of Kappa.

- Poor agreement = Less than 0.20
- Fair agreement = 0.20 to 0.40
- Moderate agreement = 0.40 to 0.60
- Good agreement = 0.60 to 0.80
- Very good agreement = 0.80 to 1.00

30. What was the main finding of the United Kingdom (BNLI NCRI) reduced dose phase III randomized control trial for follicular and marginal zone lymphoma, that compared 45 Gy in 20-23 fx against 24 Gy in 12 fx?
- A. 45 Gy had better freedom from local progression, PFS, and OS;
 - B. 45 Gy had worse freedom from local progression, PFS, and OS;
 - C. 45 Gy had equal freedom from local progression, PFS, and OS;
 - D. 24 Gy had better freedom from local progression, PFS, and OS;

Key: C

Citations: Lowry L et al. 2011; 86-92; Radiotherapy Oncology 100.

Rationale: There was no significant difference in clinical outcomes between the groups. There was more erythema in the higher dose RT arm; this phase III randomized trial, helped lower doses for follicular and marginal zone lymphoma.

31. Tumor A ($\alpha/\beta = 20$ Gy) and Tumor B ($\alpha/\beta = 2$ Gy) have the same TDC50 single dose values. After conventional fractionation over the same treatment time, the total dose to produce a TCD50 for Tumor A compared to Tumor B will be:
- A. greater.
 - B. equal.
 - C. lower.
 - D. not possible to determine.

Key: C

Citations: Radiobiology for the radiologist. Eric Hall, Amato Giaccia 2012, 395 Lippincott Williams and Wilkins 7th edition.

Rationale: Since Tumor B has a lower alpha/ beta ratio than Tumor A, it will therefore have a higher degree of sparing with fractionation. Therefore, the TDC50 for the fractionated course of radiation would be higher for Tumor B than Tumor A.

32. Cells in which phase of the cell cycle are MOST resistant to hyperthermia-induced cell killing?
- A. G1
 - B. S
 - C. G2
 - D. M

Key: A

Citations: Hyperthermia: a potent enhancer of radiotherapy. Horsman MR, Overgaard J. Clin Oncol (R Coll Radiol). 2007 Aug; 19(6):418-26.

The role of hyperthermia in optimizing tumor response to regional therapy. Moyer HR, Delman KA. Int J Hyperthermia, 24:251-261, 2008.

Rationale: Hyperthermia is most effective at killing S phase cells, while S phase cells are most resistance to radiation-induced cell killing. Hyperthermia is most effective radiosensitizer if given at the time of radiation. However, the best therapeutic effective is achieved using sequential heat treatment rather than simultaneous treatment. Sequential treatment spares normal tissue injury because of differences in blood flow between tumor and normal tissues.

33. Which produces the highest neutron dose to the patient?

- A. Passively scattered proton beam
- B. Dynamic scanning proton beam
- C. 18 MeV electron beam
- D. 10 MV photon beam

Key: A

Citations: Practical Radiation Oncology, Physics, Sonja Dieterich, 2016, 128, Elsevier, 1st edition.

Rationale: Passively scattered proton beams will have the highest neutron dose due to the devices in the beam pathway used to generate a treatable beam.

34. When using a larynx preservation approach for locally advanced SCC of the supraglottis, which treatment paradigm has the best local control?

- A. Concurrent chemoradiation
- B. Hyperfractionated radiation
- C. Induction chemotherapy then radiation
- D. Induction chemotherapy then chemoradiation

Key: A

Citations:

Forastiere, et al. 2013 Mar 1. 845-52 JCO 31(7) Long-term results of RTOG 91-11: a comparison of three nonsurgical treatment strategies to preserve the larynx in patients with locally advanced larynx cancer.

Rationale: RTOG 91-11 compared induction chemotherapy then radiation (if tumor responded), versus concurrent chemoradiation, versus daily radiation alone for preservation in locally advanced larynx cancer. Concurrent chemoradiation resulted in the best local control, larynx preservation rates as well as disease free survival. Interestingly, the 10-yr update of the results showed a trend towards worse overall survival for the concurrent chemoradiation arm due to non-cancer related deaths (Induction chemo then RT was best).

35. Which protein plays a major role in radiation-induced cellular senescence?

- A. Telomerase Reverse Transcriptase (TERT)
- B. Cytochrome C (cyt c)
- C. Retinoblastoma Protein (pRB)
- D. Receptor-Interacting Protein 1 (RIP1)

Key: C

Citations: Nat Rev Mol Cell Biol, 2010, 11: 700-714.
Antioxid Redox Signal, 2009, 11 (1): 59-98.

Rationale: The Retinoblastoma Protein (pRB) plays a key role in radiation induced senescence. pRB in a hypophosphorylated state produces cell cycle arrest. This can be accomplished via two pathways, the first involving p53 which activates p21 that in turn inhibits pRB phosphorylation by CDK2. Likewise CDK6 phosphorylation of pRB is inhibited by p16 which can be activated through the p38MAPK pathway. The p53 pathway responds mostly to open DNA double-strand breaks while p38MAPK pathway is impacted by oxidative stress. TERT, the catalytic subunit of telomerase, exerts its effects on replicative senescence not the radiation induced variety. Cytochrome c plays an active role in apoptosis while RIP1 is involved with necroptosis, a programmed version of necrosis.

36. Regarding the phase III non-inferiority trial for follicular lymphoma comparing 4 Gy versus 24 Gy (FORT trial):
- A. 4 Gy was better in term of time to progression.
 - B. 4 Gy was equivalent in terms of time to progression.
 - C. 4 Gy was worse in terms of time to progression.
 - D. 4 Gy was associated with more toxicity.

Key: C

Citations: Hoskin PJ.2014. 457-63; Lancet Oncology. 15(4).

Rationale: FORT is a prospective randomized, unblinded phase 3 non-inferiority study comparing 4 Gy vs 24 Gy for follicular lymphoma or marginal zone lymphoma. Time to local progression in the 4 Gy was not non-inferior to 24 Gy. The HR was 3.42 (95% CI 2.09-5.55 $p < 0.0001$), showing the 4 Gy was actually worse (see figure 2A in the study). Toxicity was low in both arms. Lowest was in the 4 Gy arm, as would be expected.

37. According to the Zumsteg classification for intermediate risk prostate cancer, which 61-year-old patient should have ADT + RT?
- A. cT1c, Gleason 3+4, PSA 15
 - B. cT1c, Gleason 3+3, PSA 15
 - C. cT2c, Gleason 4+3, PSA 15
 - D. cT2c, Gleason 3+4, PSA 5

Key: C

Citations: A new risk classification system for therapeutic decision making with intermediate-risk prostate cancer patients undergoing dose-escalated external-beam radiation therapy, Zumsteg, ZS2013Eur Urol. 2013, Dec;64(6):895-902. doi: 10.1016/j.eururo.2013.03.033. Epub 2013 Mar 23.

Rationale: Patients with unfavorable intermediate – risk (UIR) disease had inferior PSA-RFS (HR: 2.37; $p < 0.0001$), DM (HR: 4.34; $p = 0.0003$), and PCSM (HR: 7.39; $p = 0.007$) compared with those with favorable intermediate-risk disease, despite being more likely to receive neoadjuvant ADT.

38. In pregnant survivors of childhood cancer, what factor is associated with the highest risk of stillbirth or neonatal death?
- A. 2.5 Gy to the uterus before menarche
 - B. 2.5 Gy to the uterus after menarche
 - C. 20 Gy to the pituitary before menarche
 - D. 20 Gy to the pituitary after menarche

Key: A

Citations: Signorello, et al. Lancet, 2010, Aug 21; 376(9741):624-30.

Rationale: Girls treated with at least 2.5 Gy to the uterus or ovaries before menarche had a 13% risk of stillbirth or neonatal death. Girls treated with at least 2.5 Gy to the uterus or ovaries after menarche had a 1% risk of menarche. Pituitary dose did not correlate with stillbirth or neonatal death.

39. Which treatment technique is MOST demanding on the performance and accuracy of a treatment delivery system?
- A. 3D conformal therapy
 - B. Volumetric-modulated arc therapy
 - C. Conformal arc therapy
 - D. Segmental intensity-modulated radiation therapy

Key: B

Citations: Physics of Radiation Therapy, Khan, 430-446, Lippincott Williams Wilkins, 5th edition.

Rationale: 3D conformal therapy delivers fields sequentially at fixed gantry positions with fixed apertures and represents the simplest technique in this list. Conformal arc therapy delivers an arc while the multi-leaf collimator (MLC) moves to conform to a target. Gantry and MLC motion must be synchronized, but the MLC leaves move slowly over short distances and the output factor for a field is insensitive to leaf positioning errors due to the relatively large exposure area. Segmental “step-and-shoot” intensity-modulated radiation therapy delivers multiple field segments from each gantry angle, modulating fluence intensity using different MLC positions. Some segments may have small exposure areas where output factors change significantly with fields size, therefore requiring high leaf positioning accuracy. Volumetric-modulated arc therapy delivers an arc while the MLC moves across the entire field to modulate intensity. This is the most technically challenging as there are small field segments, leaves may be moving at maximum speed, the LINAC may be modulating the dose rate, and these are all synchronized to gantry motion.

40. Which of the following is an advantage of MR imaging over CT imaging?

- A. MRI has better geometric accuracy
- B. MRI has smaller voxel sizes
- C. MRI provides electron density information
- D. MRI generates image sets in axial, sagittal, coronal, or oblique planes

Key: D

Citations: The physics of radiation therapy, Faiz M. Khan, 2010, 415, Lippincott Williams Wilkins, 4th edition.

Rationale: MRI will provide proton density information. The CT and MRI resolution will be similar to each other (~1 mm). CT will provide the best geometric accuracy.

41. What is the 1-year OS for diffuse intrinsic pontine glioma (DIPG) patients treated with 39 Gy in 13 fractions?

- A. 26%
- B. 36%
- C. 46%
- D. 56%

Key: B

Citations: Zaghloul, et al. Radiother Oncol. 2014, Apr;111(1):35-40.

Rationale: In the Egyptian randomized trial of 71 patients, the 1y OS was 36% after hypofractionated RT vs. 26% for conventionally fractionated RT to 54 Gy. Although the 18 month PFS and OS differences were 1.1% and 2.2% respectively, the hypofractionated arm did not satisfy the non-inferiority boundaries.

42. A 60-year-old woman with a pT1N0 grade 1 ER+ invasive ductal carcinoma of the breast undergoes lumpectomy and SLNB. She plans to take endocrine therapy. What is her approximate 10-year risk of in-breast recurrence with and without RT, respectively?
- A. 1% and 5%
 - B. 2% and 8%
 - C. 8% and 15%
 - D. 8% and 22%

Key: B

Citations: Blamey R, E J Cancer, 2013, 49:2294-2302.

Rationale: The BASO-II trial randomized 1135 women with grade 1 (or favorable histology) breast cancer treated with lumpectomy and ALND in a 2x2 factorial design of: Observation, Tam, RT, Tam + RT. The per annum rates of recurrence were: Observation 2.2% Tam 0.8% RT 0.8% Tam + RT 0.2% These per annum rates were stable across the first 10 years after treatment. Both the low rate of recurrence without RT and the large relative benefit of RT are comparable to other trials of similarly well-selected patients receiving endocrine therapy (CALGB 9343, PRIME-II, ABCSG trial).

43. Regarding contouring of the brachial plexus:
- A. there are 4 nerve roots included from C5-T1.
 - B. the humeral head represents the lateral border inferiorly.
 - C. extends from the lateral aspect of the C5-T1 spinal canal.
 - D. the plexus lies just anterior to the anterior scalene muscle in the neck.

Key: C

Citations: Int J Radiat Oncol Biol Phys. Kong FM. 2011 Dec 1. 1442-57.

Rationale: 5 nerve roots (C5, C6, C7, C8, and T1) are included starting from the lateral aspect of the C5-T1 spinal canal to the space between the anterior and middle scalene. The subclavian and axillary neurovascular bundle form the lateral aspect inferiorly.

44. What is a reasonable total radiation dose for a patient with a 2cm solitary bone plasmacytoma of the left femur?
- A. 35 Gy
 - B. 45 Gy
 - C. 50.4 Gy
 - D. 54 Gy

Key: A, B, C **NOTE:** This item was keyed to A & B & C for scoring purposes upon post-exam statistical item analysis.

Citations: Radiation therapy for Solitary Plasmacytoma and Multiple Myeloma: Guidelines from the International Lymphoma Radiation Oncology Group (ILROG). June 2018. Int J Radiat Oncol Biol Phys.

Rationale: The ILROG paper states that for SBPs < 5 cm, total dose can be from 35-40 Gy. The optimal dose is not well established. The Princess Margaret reported a lack of dose-response relationship above 35 Gy for small tumors < 5 cm with 100% local control. However, higher doses may be required for more bulkier tumors.

45. Why are multiple beam angles and couch positions used for LINAC-based SRS treatments?
- A. To increase the maximum dose within the target
 - B. To decrease the maximum dose within the target
 - C. To increase the volume of medium and high doses outside of the target
 - D. To decrease the volume of medium and high doses outside of the target

Key: D

Citations: Practical Radiation Oncology, Physics, Sonja Dieterich, 2016, 233, Elsevier, 1st edition.

Rationale: At the ablative dose regimen commonly used for SRS, the high and medium doses outside of the target are of high concern, as they can cause unwanted toxicity. Minimizing the volumes outside of the target receiving high and medium doses necessitates the use of multiple beam angles and potentially multiple couch kicks.

46. When designing shielding barriers for MV linear accelerators, the use factor (U) must be determined to calculate the barrier thickness associated with which radiation source?
- A. Primary beam
 - B. Patient scatter
 - C. Head leakage
 - D. Neutrons

Key: A

Citations: Practical Radiation Oncology Physics, Dieterich S et al, 2016, Chapter 10, Elsevier, 1st edition.

Rationale: The use factor needs to be determined for the primary beam. In order to calculate the barrier transmission factor (Bpri), the use factor for each primary barrier must be known. Patient scatter, head leakage, and neutron calculations are all calculated with a use factor of 1.

47. A recent randomized trial (QUART Study) that compared optimal supportive care + steroids vs WBRT in NSCLC brain metastases, demonstrated that WBRT:
- A. improved OS.
 - B. significantly reduced steroid usage.
 - C. resulted in more significant serious adverse events.
 - D. did not improve quality-adjusted life years.

Key: D

Citations: Lancet Oncology Mulvenna P. 2016 Oct 22. 2004-14.

Rationale: The Quality of Life after Treatment for Brain Metastases (QUARTZ) study is a non-inferiority, phase 3 randomized trial demonstrated that while side effects were higher, there were not more significant adverse events in the WBRT (20 Gy in 5 fractions) arm. WBRT did not significantly affect survival or reduce steroid use. WBRT also did not significantly improve QALY.

48. The Intergroup trial (Le Pécoux) randomized patients with limited stage SCLC in complete remission after chemotherapy and thoracic radiation to standard versus higher PCI doses showed:
- A. 36 Gy PCI as the recommended dose.
 - B. an increased cancer-related mortality in the standard dose group.
 - C. no significant difference in the 2-year incidence of brain metastases.
 - D. Superior 2-year OS in the higher-dose group.

Key: C

Citations: Lancet Oncology, Le Pécoux C. 2009 May 10 (5)467-74.

Rationale: The Intergroup PCI dose trial by Le Pécoux randomized 720 limited-stage SCLC patients in complete remission after chemotherapy and thoracic radiation to standard dose PCI (25 Gy in 10 daily fractions) or a higher PCI dose of 36 Gy delivered in once daily 2 Gy fractions or twice daily 1.5 Gy fractions. There was no significant difference in the 2-year incidence of brain metastases between the standard PCI dose group and the higher-dose group, at 29% (95% CI 24-35) and 23% (18-29), respectively (hazard ratio [HR] 0.80 [95% CI 0.57-1.11], p=0.18). 2-year overall survival was 42% (95% CI 37-48) in the standard-dose group and 37% (32-42) in the higher-dose group (HR 1.20 [1.00-1.44]; p=0.05). The lower overall survival in the higher-dose group is probably due to increased cancer-related mortality.

49. BCL-2 proteins lacking the BH4 domain promote apoptosis by which mechanism?
- A. Forming pores in mitochondrial membranes
 - B. Directly activating caspases
 - C. Inhibiting anti-apoptotic BCL-2 family members
 - D. Inactivating IAP proteins

Key: A

Citations: Nat Rev Mol Cell Biol, 2008, 9:231-104.
Nat Rev Drug Discov, 2012, 11: 109-123

Rationale: BCL-2 proteins lacking the BH4 domain, BAX and /or BAK, form the mitochondrial apoptosis – induced channel (MAC) that allows the escape of cytochrome c. Cytochrome c binds with APAF1 to form the apoptosome, which in turn activates Caspase-9, an initiator caspase that begins a cascade that activates other caspases that cleave several substrates ultimately resulting in apoptosis. The anti-apoptotic BCL-2 proteins block apoptosis by preventing BCL-2 proteins only having the BH3 domain from acting to oligomerize BAX or BAK. IAP (Inhibitors of Apoptosis Proteins) act to inhibit activation of downstream effector caspases.

50. What is the rate of complete response in in muscle-invasive bladder cancer treated with TURBT and ChemoRT?
- A. 40-50%
 - B. 51-60%
 - C. 61-70%
 - D. 71-80%

Key: D

Citations: Treatment of invasive bladder cancer by cisplatin and radiation in patients unsuited for surgery. Shipley WU et al. 1987; 931-5 JAMA 258(7).

Phase I-II RTOG study (99-06) of patients with muscle-invasive bladder cancer undergoing transurethral surgery, paclitaxel, cisplatin, and twice-daily radiotherapy followed by selective bladder preservation or radical cystectomy and adjuvant chemotherapy. Kaufman DS. 2009; 833-7 Urology 73(4).

Rationale: The rate of CR is very high after TURBT+ChemoRT which is also correlated with OS.

51. The PACIFIC Trial investigated the role of durvalumab in unresectable stage III NSCLC. What is the mechanism of action of durvalumab?
- A. Inhibitor of EGFR
 - B. Antibody against PD-L1
 - C. Inhibitor of ALK
 - D. Antibody against CTLA-4

Key: B

Citations: N Engl J Med Antonia, SJ. November 16, 2017. 1919-1929; 377.

Rationale: The PACIFIC Trial randomized 713 patients with unresectable stage III NSCLC in a 2:1 ratio to receive the anti-PD-L1 antibody, durvalumab, or a placebo as consolidation therapy to begin 1 to 42 after completion of chemoradiation. Median PFS was 16.8 months in patients receiving durvalumab vs 5.6 months with placebo (HR 0.52, $p < 0.001$). Response rate was higher with durvalumab (28.4% vs 16.0%; $p < 0.001$). Median time to death or distant metastasis was longer with durvalumab (23.2 months vs 14.6 months; $p < 0.001$). Grade 3 or 4 adverse events occurred in 29.9% of patients receiving durvalumab vs 26.1% of patients receiving placebo.

52. Which lymph nodes are considered distant disease for breast cancer staging?

- A. Cervical nodes
- B. Supraclavicular nodes
- C. Intramammary nodes
- D. Rotter's nodes

Key: A

Citations: AJCC Staging Manual, 8th edition, Springer.

Rationale: Cervical nodes, contralateral internal mammary and/or axillary nodes are considered distant metastases for breast cancer staging. Regional nodes include ipsilateral supraclavicular, interpectoral, axillary (levels I-III), and internal mammary nodes. Intramammary nodes are designated as axillary nodes for staging purposes.

53. For a SRS plan prescribed to the 50% isodose line, the homogeneity index is:

- A. .5
- B. 1
- C. 1.5
- D. 2

Key: D

Citations: Int J Radiat Oncol Biol Phys. Shaw, E. 1993 Dec 1. 27 (5): 1231–39. 1993 Dec 1. 27 (5): 1231–39.

Rationale: The homogeneity index (HI) is the maximum dose divided by the prescription dose. For a radiosurgery plan, the maximum dose is 100%. Therefore, for a plan prescribed to the 50% isodose line, the HI is $100\%/50\%=2.0$. For example, for a plan prescribed to the 80% isodose line, the HI is 1.25.

54. In the absence of medical intervention, what is the LD50 for adults after a whole-body exposure?

- A. 1-2 Gy
- B. 3-4 Gy
- C. 5-6 Gy
- D. 7-8 Gy

Key: B

Citations: Radiobiology for the Radiologist, Sixth Ed. Hall and Giaccia Chapter 8 pages 117-128 Lippencott, Williams and Wilkins.

Rationale: No medical intervention is necessary if the dose is less than 2 Gy. The LD50 is 3-4 Gy which can be raised by a factor of 2 with antibiotics and other medical interventions. Dose exceeds 5 Gy then death from hematopoietic syndrome 3-4 weeks after exposure is possible. Above 10 Gy death by gastrointestinal syndrome is inevitable.

55. Why must a radiation detector be appropriately sized when measuring small fields used for SRS treatments?

- A. Large size detectors can't be positioned accurately
- B. Large detectors have inaccurate effective points of measurement
- C. Dose gradients within large detectors result in erroneous measurements
- D. Measuring low dose rates result in erroneous measurements

Key: C

Citations: Practical Radiation Oncology, Physics, Sonja Dieterich, 2016, 5, Elsevier, 1st edition.

Rationale: Using an inappropriately large detector for small fields results in erroneous measurements. There have been several instances of this which have resulted in patient mistreatments. If the detector is too large for the field, there will be dose gradients within the detector itself. The resulting value will represent an average value and thus will not provide the resolution fine enough to capture the dose gradient occurring in the medium.

56. A patient with Stage IB mycosis fungoides receiving 12 Gy at 1-1.5Gy/fraction should expect a median time to progression of:
- A. 12 weeks.
 - B. 24 weeks.
 - C. 36 weeks.
 - D. 70 weeks.

Key: C

Citations: The results of low-dose total skin electron beam radiation therapy in patients with mycosis fungoides from the UK Cutaneous lymphoma group, Morris S, 2017 Nov 1, 627-633, IJROBP.

Low-dose total skin electron beam therapy as an effective modality to reduce disease burden in patients with mycosis fungoides: results of a pooled analysis from 3 phase-II clinical trials. Hoppe, RT, 2015 Feb, 286-92, J Am Acad Dermatol.

Rationale: 12 Gy TBI is an effective regimen for patients with Mycosis fungoides.

57. Where was the LEAST likely site of first relapse in pediatric Hodgkin patients treated on the COG AHOD0031 trial with involved field RT?
- A. Exclusively at new or out of field sites of disease
 - B. Exclusively at initial sites of disease
 - C. Combination of initial sites and new or out of field sites of disease
 - D. No relapses occurred in patients treated with involved field radiation

Key: A

Citations: Int J Radiation Oncology Biol. Phys Dharmara jan 2015 May 19. 2(1):60-6.

Rationale: Almost all first relapses among patients treated with consolidative radiation occurred within treated fields, and only rarely did first relapses occur exclusively in new or out of field sites.

58. For partial kidney irradiation, what is the MOST appropriate bilateral kidney tolerance in conventional fractionation?

- A. V12 < 60%
- B. V12 < 75%
- C. V20 < 30%
- D. V20 < 45%

Key: C

Citations: Radiation-Associated Kidney Injury, Dawson LA40238Vol 76 (3): Supplement: S108-S115.

Rationale: Per the QUANTEC publication on kidney tolerance, for partial kidney irradiation the tolerances to both kidneys are V12<55%, V20<32%, V23<30%, V28<20%, mean kidney dose <18 Gy.

59. Which patient would be staged as having cT4d breast cancer?

- A. 5 cm primary breast mass, intact skin, and tumor emboli in the dermal lymphatics
- B. 8 cm primary breast mass, skin ulceration, present for 8 months
- C. 3 cm primary breast mass, diffuse erythema and edema, present for 2 months
- D. 5 cm primary breast mass, chest wall extension, and skin nodules

Key: C

Citations: AJCC Staging Manual, 8th edition; Springer; 2017.

Rationale: Inflammatory breast cancer is a clinical diagnosis staged as cT4d disease and is characterized by rapid development (<6 mos) of diffuse skin erythema and edema over a third or more of the breast. The pathologic features of tumor emboli in the dermal lymphatics is not required for this diagnosis nor is it alone sufficient for the diagnosis of IBC in the absence of skin changes. Tumor with direct extension to the chest wall is cT4a. Ulceration, skin nodules, and/or edema not meeting criteria for IBC is cT4b disease. cT4c is both T4a and T4b.

60. What are the expected 2-year locoregional control and distant freedom from progression rates following IMRT-based chemoradiotherapy for nasopharyngeal carcinoma per RTOG 0225?
- A. Locoregional: 95%, Distant: 95%
 - B. Locoregional: 90%, Distant: 85%
 - C. Locoregional: 70%, Distant: 85%
 - D. Locoregional: 70%, Distant: 50%

Key: B

Citations: J Clin Oncol. Lee et al., 27:3684-3690.

Rationale: The development of IMRT techniques has proven especially beneficial for local control of advanced nasopharyngeal cancer patients. Whereas historical outcomes from treatment at centers of excellence yielded local control ranging from 50-70% for advanced tumor stage patients, the RTOG 0225 trial demonstrated improved outcomes and serves as a benchmark for trainees (Lee et al., J Clin Oncol 27:3684-3690).

61. Which agent targets the epidermal growth factor receptor (EGFR)?
- A. Bevacizumab
 - B. Celecoxib
 - C. Sirolimus
 - D. Cetuximab

Key: D

Citations: Radiotherapy plus cetuximab for squamous-cell carcinoma of the head and neck Bonner JA et al.2006. 567-578 New England Journal of Medicine.

Rationale: The agent that blocks the epidermal growth factor receptor is Cetuximab. In a landmark trial Bonner et al. demonstrated improved clinical outcomes with the use of Cetuximab and radiation concurrent when compared to treatment with radiation alone.

62. What is the most appropriate chemotherapy for a patient who presents with distant metastases from newly diagnosed oropharyngeal SCC?
- A. Nivolumab
 - B. Pembrolizumab
 - C. Paclitaxel/Cisplatin/5FU (TPF)
 - D. Cisplatin/5FU/cetuximab (CCF)

Key: D

Citations: Platinum-based chemotherapy plus cetuximab in head and neck cancer. Vermorken, et al. 2008. NEJM 1116-27; 359(11).

Rationale: Nivolumab and Pembrolizumab are appropriate 2nd line therapies after progression on platinum-based regimens. TPF is a category 1 recommendation for induction chemotherapy when definitive treatment is planned. CCF is a category 1 recommendation for 1st line therapy for patients with metastatic disease.

63. The mechanism of action of Cisplatin is the:
- A. formation of DNA-protein crosslinks.
 - B. production of DNA crosslinks.
 - C. microtubule depolymerization.
 - D. inhibition of ribonucleotide reductase.

Key: B

Citations: The resurgence of platinum-based cancer chemotherapy. Kelland L.2007. 573-584 Nat Rev Cancer.

Rationale: Cisplatin forms crosslinks between two DNA strands, which prevents the normal synthesis of DNA which leads to cellular lethality.

64. Regarding RT for muscle invasive bladder cancer:

- A. an empty bladder is preferred during simulation and treatment.
- B. IMRT is the preferred method of treatment.
- C. treating the whole bladder without pelvic nodal RT is not acceptable.
- D. concurrent chemoRT is most successful for patients with hydronephrosis.

Key: A

Citations: Bladder Cancer. NCCN Guidelines Version 5.2018.

Rationale: Simulating and treating patients with bladder cancer when they have an empty bladder is preferred for daily reproducibility (bladder full for tumor boosts is acceptable with image guidance).

65. In breast cancer, how is an involved ipsilateral infraclavicular node clinically staged?

- A. N1
- B. N2b
- C. N3a
- D. M1

Key: C

Citations: Giuliano A, Hortobagyi GN (co-chairs), AJCC Staging Manual, 8th edition, Springer, 2017, p. 619.

Rationale: cN1-metastases to movable ipsilateral level I-II axillary LNs.
cN2b-Metastases only in ipsilateral internal mammary LNs without axillary LNs.
cN3a-Metastases in ipsilateral infraclavicular LNs.
cM1-distant metastases.

66. According to the analysis by Travis, et al (JNCI 2005) in >40,000 men with testicular cancer, what is the increased relative risk of second malignancy following RT alone?
- A. 1.0
 - B. 1.5
 - C. 2.0
 - D. 2.5

Key: This item was 0-weighted for scoring purposes upon post-exam statistical item analysis (did not count for or against candidate in calculation of test scores)

Citation: Second cancers among 40,576 testicular cancer patients: focus on long-term survivors. Travis, LB2005, J Natl Cancer Inst. 2005, Sep 21; 97(18):1354-65.

Rational: Overall patterns were similar for seminoma and nonseminoma patients, with lower risks observed for nonseminoma patients treated after 1975. Statistically significantly increased risks of solid cancers were observed among patients treated with radiotherapy alone (RR = 2.0, 95% CI = 1.9 to 2.2), chemotherapy alone (RR = 1.8, 95% CI = 1.3 to 2.5), and both (RR = 2.9, 95% CI = 1.9 to 4.2).

67. The lateral border of cervical lymph node level Ia is defined by what structure?
- A. Mandible
 - B. Digastric muscle
 - C. Submandibular gland
 - D. Sternocleidomastoid muscle

Keys: B

Citations: Grégoire , Ang, et al., 2014 Jan.

Delineation of the neck node levels for head and neck tumors: a 2013 update. DAHANCA, EORTC, HKNPCSG, NCIC CTG, NCRI, RTOG, TROG consensus guidelines.

Rationale:

The borders of level Ia are:

Cranial - Mylo-hyoid m.

Caudal - Platysma m. (caudal edge of the anterior belly of digastric mm)

Anterior - Symphysis menti

Posterior - Body of hyoid bone/mylo-hyoid m.

Lateral - Medial edge of ant. belly of digastric m.

68. What is the treatment with the BEST reported OS for a newly diagnosed glioblastoma?
- A. RT alone
 - B. RT with concurrent temozolomide and adjuvant temozolomide
 - C. RT with concurrent temozolomide and adjuvant temozolomide + bevacizumab
 - D. RT with concurrent temozolomide and adjuvant temozolomide + tumor-treating fields

Key: D

Citations:

JAMA. Stupp, Roger. 2017 Dec 19. 318 (23): 2306
New England Journal of Medicine. Gilbert, Mark R. 2014 Feb 20. 370 (8): 699–708
The Lancet Oncology. Stupp, Roger. 2009 May. 10: 8

Rationale: 60 Gy of radiotherapy (RT) with concurrent and adjuvant temozolomide (TMZ) with tumor-treating fields (TTFields) had a median overall survival (OS) of 20.9 months compared to 16.0 months without TTFields (Stupp JAMA 2017). The addition of bevacizumab did not improve OS in RTOG 0825 and the AVAglio trials.

69. What is the numerical value of the D_q parameter in the multi-target/single-hit model for a cell survival curve with an extrapolation number (n) equal to 1?
- A. 0
 - B. 1
 - C. 1.5
 - D. 2

Key: This item was 0-weighted for scoring purposes upon post-exam statistical item analysis (did not count for or against candidate in calculation of test scores)

Citations: Radiobiology for the radiologist, EJ Hall and AM Giaccia, 2012, 37-39, Lippincott, Williams and Wilkins. 7th ed.

Rationale: The multi-target/single-hit (MTSH) model is: $S = 1 - (1 - e^{-D/D_0})^n$, where S = surviving fraction, D = dose, D_0 = the mean dose required to inactivate a single target and n = number of possible targets. This model harkens back to the early days of radiation biology before mechanisms of cell killing were understood. Based on the shape of the survival curve it was postulated that there were several sensitive targets within the cell that could be inactivated. The MTSH model assumed inactivation of a single one of these targets would kill the cell. From the survival curve, the dose that reduces survival to 37% on the exponential portion of the curve (i.e. e^{-1}) is the D_0 while the number of targets n is measured by the intercept of a line extrapolated from the terminal exponential portion of the survival curve (hence is often referred to as the extrapolation number). The quasi-threshold dose D_q is a measure of the survival curve's shoulder and is the dose where the previous extrapolated line gives a surviving fraction equal to one. This can be calculated using the equation $D_q = D_0 * \ln n$. In this case, the fact that $n = 1$ indicates that there is no shoulder, making D_q zero.

70. What correctly describes the creation of x-rays and gamma rays?
- A. X-rays are created outside the nucleus; gamma rays are created within the nucleus.
 - B. X-rays are created within the nucleus; gamma rays are created outside the nucleus.
 - C. Both x-rays and gamma rays are created outside the nucleus.
 - D. Both x-rays and gamma rays are created within the nucleus.

Key: A

Citations: Physics for Diagnostic Radiology, Dendy PP and Heaton B, 2011, 15, CRC Press, 3rd edition.

Rationale: Gamma rays arise from the emission of excess nuclear energy in the form of a photon. X-rays arise from charged particles emitting energy in the form of photons when slowing down or changing atomic binding states. While their origins are different, a gamma ray and an x-ray of the same energy are indistinguishable from each other.

71. A patient presents with right neck adenopathy. Biopsy shows carcinoma positive for EBV. Imaging, examination, and EUA indicate no primary site of disease. Which staging system is used?
- A. Oropharynx
 - B. Nasopharynx
 - C. Unknown primary
 - D. Head and neck skin

Key: B

Citations: AJCC Cancer Staging Manual Patel, et al. 2017. 67-78. Springer 8th edition.

Rationale: EBV-related cervical adenopathy is staged according to the nasopharynx staging system (as T0 in this case). HPV-related cervical adenopathy is staged according to the HPV-mediated oropharyngeal cancer staging system. The staging system for unknown primary is used for squamous cell carcinoma and salivary gland carcinoma of all head and neck sites except HPV-related oropharynx cancer, nasopharynx cancer, melanoma, thyroid carcinoma, and sarcoma.

72. The expression of what cytokine is linked with radiation induced pneumonitis?

- A. Transforming growth factor- β 1 (TGF- β 1)
- B. Tumor necrosis factor- α (TNF- α)
- C. NF-kappaB (NF-kB)
- D. Interleukin-6 (IL-6)

Key: A

Citations: The use of blood biomarkers to predict radiation lung toxicity: a potential strategy to individualize thoracic radiation therapy. Kong FM, Ao X, Wang L, Lawrence TS, Cancer Control 15: 140–150 (2008).
TGF-beta1 and radiation fibrosis: a master switch and a specific therapeutic target? Martin M, Lefaix J, Delanian S, Int J Radiat Oncol Biol Phys 47: 277–290 (2000).
Radiobiology for the Radiologist, Sixth Ed., Hall and Giaccia, Chapter 19 p332-333.

Rationale: Transforming growth factor beta 1(TGF- β 1) gene controls proliferation and cellular differentiation. TGF- β 1 is an important modulator of the inflammatory response and in the development of tissue fibrosis in irradiated lungs. Animal and human studies have demonstrated that TGF- β 1 is a major regulator of radiation-induced lung injury. Administration of anti-TGF- β 1 antibodies can decrease the inflammatory response and reduce TGF- β 1 activation several weeks after radiotherapy.

73. What is the appropriate management of a pathologic stage T2bN0M0 squamous cell carcinoma of the cervix after a radical hysterectomy with lymphadenectomy?

- A. Observation
- B. EBRT
- C. ChemoRT
- D. Chemotherapy

Key: C

Citations: J Clin Oncol. 2000 Peters WA. 18(8):1606-13.

Rationale: Patients with clinical stage IA2, IB, and IIA carcinoma of the cervix, initially treated with radical hysterectomy and pelvic lymphadenectomy, and who had positive pelvic lymph nodes and/or positive margins and/or microscopic involvement of the parametrium (such as this patient) were studied in the Intergroup 0107 trial. Women were randomized to receive RT or RT + CT. Each group received 49.3 Gy in 29 fractions using standard pelvic fields. Chemotherapy consisted of cisplatin 70 mg/m² and a 96-hour infusion of fluorouracil 1,000 mg/m²/d every 3 weeks for 4 cycles, with the first and second cycles given concurrently to RT. Between 1991 and 1996, 268 patients were entered into the study. Progression-free and overall survival was statistically significantly improved in the patients receiving CT.

74. Which is NOT involved in oncogene activation?

- A. Gene amplification
- B. Point mutation
- C. DNA methylation
- D. Chromosomal translocation

Key: C

Citations: Adv. Genet, Kulis, 2010, 70:27-56.

Rationale: DNA methylation is associated with the silencing of gene expression and is typically associated with tumor suppressor gene silencing. Gene amplification, point mutations and chromosomal translocations are all associated with excess normal protein expression or abnormal (hyperactive) protein expression which are key features on oncogenes.

75. During total skin electron therapy, a beam spoiler is placed near the patient upstream from the incident beam to:

- A. increase the electron beam energy.
- B. shield the bremsstrahlung contamination.
- C. decrease the dose-rate of treatment.
- D. increase the wide-angle scatter of the beam.

Key: D

Citations: Practical Radiation Oncology Physics, Sonja Dieterich, 2016, 317, Elsevier, 1st edition.

Rationale: During total skin electron therapy, a beam spoiler is placed near the patient upstream from the incident beam to increase the wide-angle scatter of the beam such that the dose homogeneity improves.

76. What is the approximate local control after radiation for pituitary adenomas?

- A. >90%
- B. 70%
- C. 55%
- D. 36%

Key: A

Citations: Radiation therapy in the management of pituitary adenomas. Loeffler JS, Shih HA. 2011 Jul. 96(7):1992-2003. J Clin Endocrinol Metab.

Rationale: The local control for pituitary adenomas is greater than 90% with radiation therapy.

77. According to the long term analysis of SWOG S8736, patients with DLBCL who received 8 cycles of CHOP compared with 3 cycles of CHOP +RT had:

- A. significantly lower rates of secondary breast cancers.
- B. significantly higher rates of secondary breast cancers.
- C. lower rates of cardiovascular deaths.
- D. higher rates of cardiovascular deaths.

Key: D

Citations: Stephens et al.2016. Journal Clinical Oncology. 2997-3004 JCO. 34(25).

Rationale: Long term results of the CHOP x8 vs CHOP x3 +RT, demonstrates higher rates of cardiovascular deaths from CHOPx8, while there were similar rates of second breast cancers. There were 15 cardiovascular deaths in CHOP x 8 arm compared with 8 in the CHOP3RT arm.

78. What is the smallest circular field diameter sufficient to establish lateral scatter equilibrium on the central axis of a 6 MeV electron beam?
- A. 1.5 cm
 - B. 3.0 cm
 - C. 4.5 cm
 - D. 6.0 cm

Key: C

Citations: Physics of Radiation Therapy, Khan, 2003, 313-314, Lippincott Williams Wilkins, 3rd edition.

Rationale: The equation for the field radius to ensure lateral scatter equilibrium is $R_{eq} = 0.88 \cdot \sqrt{E}$, where E is the most probable electron energy. So, for 6 MeV $R_{eq} = 2.16$ cm, leading to a minimum ~4.5 cm field diameter to ensure equilibrium. Loss of lateral scatter equilibrium in “narrow” beams results in significant changes to the depth-dose properties of the electron beam as a function of field size. For “broad” beams with fields large enough to have central axis lateral scatter equilibrium, depth-dose properties are essentially constant as a function of field size.

79. According to Memorial Sloan Kettering Cancer Center (MSKCC) prognostic model for metastatic renal cell carcinoma, which is NOT a poor prognostic factor?
- A. Serum LDH greater than 1.5 times the upper limit of normal
 - B. Corrected serum calcium lower than upper limit of normal
 - C. Serum haemoglobin less than the lower limit of normal
 - D. Interval from diagnosis to treatment of less than one year

Key: B

Citations: Interferon-alfa as a comparative treatment for clinical trials of new therapies against advanced renal cell carcinoma. Motzer RJ, Bacik J, Murphy BA, et al. 2002; 20:289-296. J Clin Oncol.

Rationale: Poor prognostic factors are:

- Interval from diagnosis to treatment of less than 1 year
- Karnofsky performance status less than 80%
- Serum lactate dehydrogenase (LDH) greater than 1.5 times the upper limit of normal (ULN)
- Corrected serum calcium greater than the ULN
- Serum haemoglobin less than the lower limit of normal (LLN)

80. In a retrospective comparison of SBRT versus radiofrequency ablation in hepatocellular cancer (Wahl et al, 2016), improved freedom from local progression was observed with:

- A. SBRT for tumors > 2 cm.
- B. SBRT for tumors < 2 cm.
- C. RFA for tumors < 2 cm.
- D. RFA for tumors > 2 cm.

Key: A

Citations: Wahl et al. 2016. Outcomes After Stereotactic Body Radiotherapy or Radiofrequency Ablation for Hepatocellular Carcinoma. JCO 452-459.

Rationale: In Wahl et al 2016, outcomes of patients with HCC treated with SBRT and RFA were retrospectively compared. Freedom from local progression was improved in the patients who received SBRT compared to those who received RFA. On univariate analysis for local progression, treatment type (RFA vs SBRT) and tumor size were statistically significant, while age, tumor size, CP score, AFP and prior treatments were not. For tumors smaller than 2 cm, there was no significant difference between RFA and SBRT in FFLP (HR, 2.50; 95% CI, 0.72 to 8.67; P = .15), but for tumors 2 cm or larger, RFA was associated with significantly worse FFLP (HR, 3.35; 95% CI, 1.17 to 9.62, P = .025).

81. A new imaging algorithm detects immunotherapy response in 48 of 50 patients with known response, and 40 of 50 patients known not to have had an immune response. What is the specificity of the test?

- A. 20%
- B. 54.6%
- C. 83.3%
- D. 96%

Key: A

Citations: Basic & Clinical Biostatistics, Saunders & Trapp, 1999, 232-4, Appleton and Lange, 2nd edition.

Rationale: Specificity is the probability that a test result will be negative when the disease is not present (true negative rate). This is calculated as # of true negative / (false positive + true negative). A is the sensitivity of the algorithm. C is the positive predictive value of the algorithm. D. is the negative predictive value of the algorithm.

82. What percentage of nasopharyngeal cancer patients completed all 3 cycles of adjuvant chemotherapy in the landmark Intergroup 0099 (“Al-Sarraf”) study?

- A. 15%
- B. 35%
- C. 55%
- D. 75%

Key: C

Citations: Chemoradiotherapy versus radiotherapy in patients with advanced nasopharyngeal cancer: phase III randomized Intergroup study 0099. Al-Sarraf, et al. 1998. 1310-1317; JCO 16(4).

Rationale: The Intergroup 0099 clinical trial compared definitive radiation therapy with definitive radiation and both concurrent and adjuvant chemotherapy. Only 63% of patients received all 3 cycles of concurrent cisplatin and 55% received all 3 cycles of adjuvant cisplatin/5FU.

83. What is the most common subgroup of medulloblastoma in infants?

- A. WNT
- B. SHH
- C. Group 3
- D. Group 4

Key: B

Citations: Kool, et al. Acta Neuropathol. 2012, Apr;123(4):473-84.

Rationale: Among infants and adults, SHH tumors are the most common subtypes. SHH tumors in infants have a high frequency of desmoplastic histology.

84. Per QUANTEC, what is the mean liver dose constraint for 3-fraction SBRT for primary liver cancer?

- A. 13 Gy
- B. 16 Gy
- C. 19 Gy
- D. 21 Gy

Key: A

Citations: Pan CC. 2010. Radiation Associated Liver Injury. IJROBP. Vol 76 (3): Supplement: S94-S100.

Rationale: Per QUANTEC for radiation associated liver injury, constraints for SBRT include:

- < 13 Gy for primary liver cancer, in three fractions
- < 18 Gy for primary liver cancer, in six fractions
- < 15 Gy for liver metastases, in three fractions
- < 20 Gy for liver metastases, in six fractions

85. In the NCCTG 86-47-51 study evaluating 5-FU administration concurrently with postoperative RT for rectal cancer, compared to bolus 5-FU, continuous infusion 5-FU increased:

- A. leukopenia.
- B. dermatitis.
- C. distant metastases.
- D. overall survival.

Key: D

Citations: O'Connell MJ et al. 1994. Improving adjuvant therapy for rectal cancer by combining protracted-infusion fluorouracil with radiation therapy after curative surgery. NEJM 331(8):502-507.

Rationale: 666 patients with TNM stage II or III rectal cancer received intermittent bolus injections or protracted venous infusions of fluorouracil during postoperative radiation to the pelvis. They also received systemic chemotherapy with semustine plus fluorouracil or with fluorouracil alone in a higher dose, administered before and after the pelvic irradiation. With a median follow-up of 46 months among surviving patients, patients who received a protracted infusion of fluorouracil had a significantly increased time to relapse ($P = 0.01$) and improved survival ($P = 0.005$). PVI 5-FU showed increased rates of diarrhea whereas bolus 5-FU showed more leukopenia.

86. What is the MOST appropriate PTV margin when treating an arteriovenous malformation with SRS?
- A. 0-2 mm
 - B. 3-5 mm
 - C. 6-8 mm
 - D. 8-10 mm

Key: A

87. James et al. (NEJM 2012) reported that synchronous chemotherapy with 5FU and mitomycin C combined with RT significantly improved LRC of bladder cancer, as compared with RT alone, with no significant increase in adverse events. In this study, how was the RT administered?
- A. Empty bladder; tumor with a 1 cm margin to 64 Gy
 - B. Full bladder; whole pelvis to 45 Gy; bladder boost to 64 Gy
 - C. Full bladder; bladder + pelvic LNs to 45 Gy; bladder boost to 64 Gy
 - D. Empty bladder with 1.5 cm margin + extra-vesical extent of tumor with a 2 cm margin to 64 Gy

Key: D

Citations: National Comprehensive Cancer Network. Bladder Cancer, version 4.2018. Accessed June 12, 2018. N Engl J Med. James et. al. 2012 Apr 19. 366(16):1477-88.

Rationale: In the James study, patients were treated to an empty bladder with a 1.5 cm margin plus extra-vesical extent of tumor with a 2cm margin. Alternatively, they could be treated to an empty bladder to a gross tumor volume (GTV) plus a 2 cm margin, or with 2 phases where they treated the whole bladder and the reduced volume. The dose was either 64Gy in 32 fractions or 55Gy in 20 fractions. NCCN does suggest treatment of the empty bladder and pelvic lymph nodes to 45 Gy, followed by a boost to the empty bladder to a cumulative dose of 64 Gy, although full bladder may be appropriate with image guidance. Whole Pelvis field are likely too large and any treatment with full bladder inappropriate without image guidance.

88. With a mean dose to the cochlea of 45 Gy using conventional fractionation (i.e. ≤ 2 Gy per fraction), what is the risk of sensory-neural hearing loss?

- A. 5%
- B. 10%
- C. 20%
- D. 30%

Key: D

Citations: Use of normal tissue complication probability models in the clinic. Marks, et al. 2010. IJROBP, S10–S19; 76(3 Suppl).

Rationale: If the mean dose to the cochlea is at or below 45 Gy then the risk of damage to hearing at 4 kHz is less than 30%.

89. What is the MOST dose limiting side effect of TBI?

- A. Cardiac failure
- B. Pancreatitis
- C. Pneumonitis
- D. Enteritis

Key: C

Citations: Chapter 15: Total Body Irradiation in Textbook of Radiation Oncology, Barker CA, 2010, 284, Leibel and Phillips.

Rationale: Lung toxicity is the dose limiting toxicity.

90. Which of the following is FDA approved for use as a medical countermeasure in the event of a radiation emergency?

- A. Granulocyte/Macrophage Colony Stimulating Factor
- B. Keratinocyte growth factor
- C. Amifostine
- D. Pembrolizumab

Key: A

Rationale: Keratinocyte growth factor has been studied for the prevention of radiation mucositis; amifostine is used to reduce the side effects of chemotherapy and radiation; pembrolizumab is an immune checkpoint inhibitor; none of these compound is approved for use in a radiation emergency. Sargramostim is indicated to increase survival in patients exposed to myelosuppressive doses of radiation

91. What location in the femur is associated with increased risk of fracture following limb sparing surgery and radiation for soft tissue sarcoma?

- A. Femoral body
- B. Femoral neck
- C. Intertrochanteric region
- D. Subtrochanteric region

Key: B

Citations: Dickie et al, IJROBP, 2009:75(4), 1119-1124.
Pak et al., IJROBP, 2012:83(4), 1257-1263.

Rationale: In a study of dose effect relationships of risk for femoral fractures, Pak et al noted the femoral neck was at increased risk as compared to other anatomic regions and that fracture risk increases with mean femoral neck doses > 40Gy. While not seen in this study, other studies have also shown associations with age, female gender, use of chemotherapy, tumor size, RT timing. Periosteal excision may increase fracture risk, though this was not seen in this study given their institutional practice of prophylactic intramedullary nailing for high risk patients. Dickie et al showed lower fracture risk with mean dose to bone < 37Gy.

92. For pleomorphic adenoma of the parotid gland, which feature increases the risk of local recurrence?

- A. Patient age
- B. Tumor size
- C. Male gender
- D. Tumor spillage

Key: D

Citations: Benign parotid adenomas: a review of the Princess Margaret Hospital experience. Liu, et al. 1995, 177-83. Head Neck 17(3).

Rationale: Surgical excision with a superficial or complete parotidectomy and facial nerve preservation is the recommended treatment for pleomorphic adenoma. Tumor spillage, residual disease, and recurrent disease after initial surgery are risk factors for additional recurrence. With a margin-negative surgical excision, size is not an independent risk factor for recurrence of a pleomorphic adenoma.

93. According to RTOG 1112, a phase 3 randomized trial comparing sorafenib to SBRT followed by sorafenib for hepatocellular cancer, prescription dose to the tumor should be adjusted according to:

- A. tumor size.
- B. tumor location.
- C. mean liver dose.
- D. patient liver function.

Key: C

Citations: <https://www.clinicaltrials.gov/ct2/show/NCT01730937>.

https://www.rtog.org/Portals/0/RTOG%20Broadcasts/Attachments/1112_master_w_update_5.7.13.pdf

Dawson, L. RTOG 1112 Study Protocol.

Rationale: RTOG 1112 scales the dose down from a maximum prescription dose of 50 Gy in 5 fractions according to the mean dose in an iterative fashion, until the mean dose achieved with a reduced prescription dose is less than or equal to the mean liver tolerance.

94. A 70-year-old undergoes a radical nephrectomy for an 8 cm renal mass. The tumor was papillary subtype and was limited to the kidneys with negative margins. Which management option is MOST appropriate?
- A. Administration of Sunitinib
 - B. Administration of Interleukin 2
 - C. Radiation Therapy to the post-operative bed
 - D. Surveillance

Key: D

Citations: NCCN Guidelines, Kidney cancer v.3.4018.

Rational: High risk features of resected renal cell cancer include tumor stage 3 or higher and regional lymph node metastases. In patients with stage II or III disease with clear cell histology and high-risk features adjuvant therapy with sunitinib can be considered. In patients with stage II or III disease without clear cell histology and no high-risk features, surveillance is recommended.

95. What is the MOST likely paraneoplastic presentation in a patient with thymoma?
- A. Muscle weakness that improves with exercise
 - B. Recent weight loss and high spiking fevers
 - C. Hypercalcemia
 - D. Blurry vision worse towards end of the day

Key: D

Citations: Up-to-date: Thymoma and thymic carcinomas. Meneshian A, Giaccone G, and Olivier K43221.

Rationale: A is incorrect since this is a sign of Lambert Eaton syndrome, a hallmark of paraneoplastic syndrome found in small cell lung cancer. B is incorrect since these are signs of B symptoms in lymphomas. C is incorrect since this is a sign of squamous cell carcinoma of the lung. D is correct since having blurry vision from double vision due to myasthenia gravis, a condition strongly associated with having a thymoma.

96. In children, what medulloblastoma subgroup has the best prognosis?

- A. WNT
- B. SHH
- C. Group 3
- D. Group 4

Key: A

Citations: Kool, et al. Acta Neuropathol. 2012, Apr; 123(4):473-84.

Rationale: 5 and 10 y OS for children with WNT-pathway medulloblastoma is 95%. Trials of reduced-intensity therapy for children with WNT-pathway tumors are ongoing.

97. According to Caloglu et al. 2011, a retrospective study analysing PSA rise after I-125 monotherapy in patients with prostate cancer, what was the median time to first PSA rise of ≥ 0.2 in patients who developed biochemical failure vs. those who experienced a benign and transient PSA bounce?

- A. 3.6 months vs. 12.4 months
- B. 12.4 months vs. 3.6 months
- C. 17.4 months vs. 34.3 months
- D. 34.3 months vs. 17.4 months

Key: D

Citations: Int J Radiat Oncol Biol Phys. 80.

Rationale: PSA bounce is a known phenomenon following prostate brachytherapy that can be confused with biochemical failure. It is important to understand the expected PSA response following brachytherapy and how the interval between PSA rise and implant is related to the likelihood of biochemical failure. A PSA rise that is benign tends to occur sooner after treatment compared to a PSA rise which represents biochemical failure.

98. What change is incorporated in the 2018 AJCC staging guidelines for soft tissue sarcoma?

- A. Histologic grade is no longer included
- B. N1 is Stage group III
- C. Retroperitoneal location is staged separately
- D. T3 includes tumors from 10-20 cm

Key: C

Citations: AJCC cancer staging manual, 8th ed., Springer, New York, 2017.

Rationale: The 8th edition incorporates many changes including new STS staging systems based on anatomic location for data collection, new size categories for T stage, and new prognostic stage groups for nodal disease (now N1 disease is stage IV). Grade remains included. T3 tumors are >10 cm and ≤15 cm; T4 tumors are >15 cm.

99. Based on the National Lung Cancer Screening Trial (NLST), which of the following parameters from smoking history is NOT a risk factor to select patients for lung cancer screening?

- A. ≥30 pack-year smoking history
- B. Smoking cessation < 15 years
- C. Age 55-74 years
- D. Second-hand smoking history

Key: D

Citations:

NCCN Guidelines V1.2019.

N Engl J Med. National Lung Screening Trial Research Team. 2011 Aug 365(5):395-409.

Rationale: Eligible study participants in the NLST were between 55 and 74 years of age at the time of randomization, had a history of cigarette smoking of at least 30 pack years, and, if former smokers, had quit within the previous 15 years. Persons who had previously received a diagnosis of lung cancer, had undergone chest CT within 18 months before enrollment, had hemoptysis, or had an unexplained weight loss of more than 6.8 kg (15 lb) in the preceding year were excluded. Second-hand smoking history was NOT included in the equation. NCCN guidelines note that second-hand smoke, is NOT independently considered a risk factor for lung cancer screening.

100. What number of mitotic figures per 10 HPFs define meningiomas as grade III?

- A. 3
- B. 5
- C. 10
- D. 20

Key: D

Citations: WHO Classification of Tumours of the Central Nervous System. Chapter 10 Meningiomas. Louis et al. 2016. Stylus Publishing, LLC. Revised 4th edition.

Rationale: Meningiomas a grade by mitotic figures among other features. Grade III meningiomas have 20 or more mitotic figures per 10 HPF.

101. For patients with newly diagnosed primary CNS lymphoma, the recommended chemotherapy includes:

- A. CHOP.
- B. Methotrexate.
- C. BEACOPP.
- D. ABVD.

Key: B

Citations: The Lancet Oncology. Hoang-Xuan. 2015 July. 16 (7): e322–e332.

Rationale: Methotrexate in high-doses (typically 3 g/m² or more), in combination with other agents, is the standard primary chemotherapy. Systemic non-Hodgkin lymphoma regimens such as CHOP, are not recommended. BEACOPP and ABVD are typically for Hodgkin lymphoma.

102. What is the 10-year risk of progression of solitary bone plasmacytoma to multiple myeloma?

- A. 10-25%
- B. 30-50%
- C. 65-85%
- D. 100%

Key: C

Citations: Outcomes and patterns of failure in solitary plasmacytoma: A multicenter Rare Cancer Network study of 258 patients. Ozsahin M, Tsang RW, Poortmans P, et al. 2006; 64:210-217. Int J Radiat Oncol Biol Phys.

103. A study evaluates the efficacy of a chemotherapy agent used to treat lung cancer and identifies the most common side effects prior to a large-scale study. This is an example of what kind of clinical trial?

- A. Pilot study
- B. Phase I
- C. Phase II
- D. Phase III

Key: C

Citations: Basic and Clinical Biostatistics, Dawson B and Trapp RG, 2004, pp 333 and 404, McGraw-Hill, 4th edition.

Rationale: Phase I: Researchers test a new drug or treatment in a small group of people for the first time to evaluate its safety, determine a safe dosage range, and identify side effects. Phase II: The drug or treatment is given to a larger group of people to see if it is effective and to further evaluate its safety. Phase III: The drug or treatment is given to large groups of people to confirm its effectiveness, monitor side effects, compare it to commonly used treatments, and collect information that will allow the drug or treatment to be used safely.

104. A new head and neck treatment protocol proposes using accelerated hyper-fractionation. What would be the radiobiological rationale of the new protocol compared to conventional fractionation?

- A. Decreased early toxicity
- B. Decreased late toxicity
- C. Increased tumor control
- D. Similar tumor control

Key: B

Citations: Radiobiology for the radiologist Eric Hall, Amato Giaccia 2012, 398 Lippincott Williams and Wilkins 7th edition.

Rationale: Head and neck cancers have high alpha/beta ratios. Therefore, the hyper-fractionated schedule would likely decrease the incidence of late toxicity while having a similar likelihood of tumor control when compared to standard fractionation. This was the biological basis of the CHART trials

105. The maximum kinetic energy of an electron set in motion by Compton scattering of a 10 MeV photon is:

- A. 10.00 MeV
- B. 9.75 MeV
- C. 9.49 MeV
- D. 5.00 MeV

Key: B

Citations: The Physics and Technology of Radiation Therapy, McDermott Orton, 2010, 6-7, Medical Physics Publishing, 1st edition.

Rationale: The scattered electron has its maximum energy when the photon is backscattered. A high energy photon that is backscattered has an energy of 0.255 MeV, therefore the electron will acquire an energy of $10.0 - 0.25 = 9.75$ MeV

106. What subsequent treatment(s) would be recommended to a 43-year-old female with newly diagnosed cT4dN2M0 triple negative breast carcinoma who has an excellent clinical response to neoadjuvant chemotherapy?

- A. Breast conserving surgery and sentinel lymph node biopsy followed by adjuvant WBI+RNI
- B. Simple mastectomy with sentinel lymph node biopsy and contralateral prophylactic mastectomy, followed by PMRT
- C. Modified radical mastectomy with immediate reconstruction followed by PMRT if residual disease
- D. Modified radical mastectomy followed by PMRT

Key: D

Citations: Dawood et al., *Annals of Oncol*, 2011; 22(3), p. 515-523.

Rationale: Inflammatory breast cancer is an aggressive form of breast cancer with poor prognosis for which multidisciplinary approach and trimodality care is recommended. Treatment involves neoadjuvant systemic chemotherapy with assessment of response, followed by modified radical mastectomy, and PMRT. Immediate reconstruction, breast conserving surgery, and sentinel lymph node biopsy are not recommended. PMRT is recommended regardless of response to neoadjuvant chemotherapy.

107. The relative exposure rate of an x-ray generator is proportional to:

- A. kVp.
- B. kVp².
- C. mAs².
- D. mAs^{1/2}.

Key: B

Citations: *The Physics of Radiation Therapy*, Khan, 2010, 33, Lippincott, Williams Wilkins, 4th edition.

Rationale: The exposure rate is proportional to the mAs and the square of kVp.

108. What is linear attenuation coefficient (μ)?

- A. The energy lost per unit length during x-ray interaction with matter
- B. The interaction probability per unit length during x-ray interaction with matter
- C. The energy lost per unit length during the ion particle interaction with matter
- D. The interaction chance per unit length during the ion particle interaction with matter

Key: B

Citations: The physics of radiation therapy, Faiz M. Khan, 2010, 55, Lippincott Williams Wilkins, 4th edition.

Rationale: $\mu = dI/(Idx)$, where I is the intensity, dx is the matter thickness.

109. In the phase II study (RTOG 0937) of extensive stage SCLC patients randomly assigned to PCI alone vs. PCI and consolidative radiation therapy (45 Gy / 15 fractions) to all residual sites, the addition of consolidative RT:

- A. increased toxicity with no impact on progression or OS.
- B. improved both time to progression and OS without increase in toxicity.
- C. improved time to progression with expected rates of higher toxicity.
- D. did not impact toxicity, time to progression or OS.

Key: C

Citations: Journal of Thoracic Oncology, Elizabeth M. Gore et al. June 15, 2017; 1561-1570.

Rationale: Gore et al. study of ES-SCLC patients with response with oligoresidual disease (1-4) was RCT of PCI alone vs. PCI and consolidative RT (45Gy / 15 fractions) to sites of residual disease. This showed improved time to progression with the addition of consolidative RT (HR 0.53, 95% CI: 0.32 – 0.87, p=0.01). There was a non-significant difference in 1-year OS (60.1% vs. 50.8%, respectively, P=0.21). This was found at planned interim analysis as the study crossed futility boundary for OS and was closed prior to meeting accrual target. Toxicity was as anticipated with the therapy delivered. The rates of grade 3+ toxicity were 23% for PCI and 36% for PCI+cRT (p = 0.24).

110. In AAPM TG-51, the raw charge reading collected by an ion chamber must be corrected for air temperature and pressure if the ion chamber:

- A. has a small collecting volume.
- B. is vented to the atmosphere.
- C. is used for electron beam measurements.
- D. is used to measure high dose rate beams (>1000 MU/min)

Key: B

Citations: The Physics of Radiation Therapy, Khan, 2003, Chapter 8, Lippincott Williams Wilkins, 3rd edition.

Rationale: During TG-51 absolute dose calibration of a photon or electron beam, an air temperature and pressure correction must be applied if the ion chamber is vented to the atmosphere. The correction accounts for the changes in air mass within the collecting volume of the chamber due to changes in air temperature and/or pressure.

111. In the series of 79 inoperable intrahepatic cholangiocarcinoma patients by Tao et al., published in JCO in 2016, what was associated with improved OS?

- A. Biologic equivalent dose delivered
- B. Decreased largest dimension of primary tumor
- C. ECOG performance status 0
- D. Absent satellitosis at diagnosis

Key: A

Citations: J Clin Oncol. Jan 20, 2016; 34(3):219-26.

Rationale: This series described patients with intrahepatic cholangiocarcinoma, treated with escalated doses of radiation, and found that doses with a BED >80.5 were associated with improved local control and overall survival. On multivariate analysis (encompassing all of the choices listed in A, B, C and D) only radiation dose (expressed as biologic equivalent dose) was associated with a statistically significant improvement in local control or overall survival.

112. TGF- β leads to the activation of which downstream signaling pathway primarily involved with epithelial–mesenchymal transition (EMT) and tissue fibrosis?

- A. JAK
- B. LAP
- C. SMAD
- D. ROCK

Key: C

Citations: Nat Rev Cancer, Bentzen-SM, 2006, Nat Rev Cancer. Sep; 6(9):702-13.

Rationale: Epithelial–mesenchymal transition (EMT) of cells has long been recognized as an important part of embryonic development, but more recent data suggest that EMT occurs during wound healing and fibrogenesis in adult tissues. In the case of renal fibrosis, it has been estimated that more than a third of all disease-related fibroblasts stem from tubular epithelia. It is probable that EMT has an important role in radiation fibrogenesis, and studies have shown that the loss of SMAD3 blocks EMT and reduces fibrogenesis. There is also a strong experimental case for the mobilization of bone-marrow stem cells and human mesenchymal stem cells as an important element in the processing of radiation injury.

113. Which quantity ALWAYS decreases as the number of measurements increases?

- A. Standard error of the mean
- B. Standard deviation
- C. Variance
- D. Mean

Key: A

Citations: Primer of Bio-Statistics. Glantz, SA199727-28.

Rationale: The standard error of the mean is the standard deviation of the distribution divided by the square root of the number of measurements. Thus, as the number of measurements increases, the uncertainty in the mean value of the distribution decreases.

114. Which group has the highest prevalence of oral HPV infection per the National Health and Nutrition Examination Survey (NHANES)?
- A. Women age 34-39
 - B. Men age 40-44
 - C. Women age 50-54
 - D. Men age 55-59

Key: D

Citations: Oral Human Papillomavirus Infection: Differences in Prevalence Between Sexes and Concordance With Genital Human Papillomavirus Infection, NHANES 2011 to 2014.

Sonawane et al. 2017. *Ann Intern Med.* 714-24; 167(10).

Prevalence of oral HPV infection in the United States, 2009-2010. Gillison et al. 2012. *JAMA* 307(7).

Rationale: NHANES data from 2009-2010 is bimodal with a peak incidence in men at about 55 years old and a nadir at about 40 years old. According to data from 2011 – 2014, men age 55-59 have a prevalence of 14.6% and men age 40-44 have a prevalence of 11.0%. The prevalence in women is much lower at 3.2% overall.

115. In the testes, what dose range in 2 Gy fractions produces permanent sterility?

- A. 1-2 Gy
- B. 2-4 Gy
- C. 4-6 Gy
- D. 6-8 Gy

Key: D

Citations: Radiobiology for the Radiologist, Sixth Ed., Hall and Giaccia, Chapter 19, p340-341.

Rationale: In humans, doses as low as 0.15 Gy was cause temporary sterility. Azoospermia for longer than 12 months can occur after a single dose of 2 Gy, with permanent azoospermia after 6 Gy-8 Gy delivered in 2 Gray fractions. Fractionation is more effective at killing stem cells in the testes because the first dose stimulates radioresistance cells to move through the cell cycle into more radiosensitive phases which are killed by subsequent treatments. Likewise, azoospermia is sensitive to low dose rate treatments.

116. According to AAPM TG142, it is recommended that treatments cannot proceed if the daily output deviates from the expected value by:
- A. 1%.
 - B. 3%.
 - C. 5%.
 - D. 10%.

Key: C

Citations: Task Group 142 report: Quality assurance of medical accelerators, Klein, EE et al. 2009, 4197-4212, Medical Physics 36 (9).

Rationale: While an output deviation between 3% and 5% should be investigated as soon as possible, any deviation of 5% or more should be resolved before any treatments can proceed.

117. What expansion should be placed on the proximal edge of primary tumor GTV when creating a CTV for a cT3N0 esophageal cancer?
- A. 0.5 cm
 - B. 2.0 cm
 - C. 3.5 cm
 - D. 5.0 cm

Key: C

Citations: Expert consensus contouring guidelines for IMRT in esophageal and gastroesophageal junction cancer Abraham J. Wu, MD, Walter R. Bosch, D.Sc., Daniel T. Chang, MD, Theodore S. Hong, MD, Salma K. Jabbour, MD, Lawrence R. Kleinberg, MD, Harvey J. Mamon, M.D. Ph.D., Charles R. Thomas, Jr., MD, and Karyn A. Goodman, MD.

Rationale: For the proximal margin of esophageal cancers, the proximal Border should be 3-4cm margin above the proximal edge of the GTV, or 1cm above any grossly involved periesophageal nodes, whichever is more cephalad. This margin should be oriented along the esophageal mucosa, instead of being a simple geometric expansion. For very proximal tumors, the upper border should not extend above the level of the cricoid cartilage unless there is gross disease at that level.

118. In the CONVERT trial, a randomized trial for limited stage SCLC patients comparing 45 Gy delivered BID versus 66 Gy once daily:
- A. median PFS was comparable.
 - B. median OS was better with once-daily fractionation.
 - C. acute grade 3-5 esophagitis was reported in about 30% of both cohorts.
 - D. acute grade 3-5 pneumonitis was reported in about 10% of both cohorts.

Key: A

Citations: Lancet Oncol. Faivre-Finn 18:1116-25.

Rationale: In the Concurrent once-daily versus twice-daily chemoradiotherapy in patients with limited-stage small-cell lung cancer (CONVERT) study, an open-label, phase 3, randomised, superiority trial: Median PFS was comparable (15.4 vs 14.3 m, HR 1.12 [95% CI 0.92–1.38]; p=0.26) between the two groups no differences in local or metastatic PFS. Overall radiotherapy toxicity was also comparable in both cohorts: Acute grade 3-5 esophagitis: 19% Acute grade 3-5 pneumonitis: 3% Late grade 3-5 esophagitis: 2% Late grade 3-5 pneumonitis: 3% These numbers can guide treatment discussion with patients.

119. Which is the most abundant type of DNA damage caused by low LET ionizing radiation?
- A. Double strand breaks
 - B. Single strand breaks
 - C. Sugar damage
 - D. Base damage

Key: D

Citations: Radiobiology for the Radiologist, Hall and Giaccia, 2012, 358-359, Chapter 17th edition, Lippincott, Williams and Wilkins.

Rationale: Typically, there are 1000-2500 base damages, 40 double strand breaks, 1000 single strand breaks and 800-1600 sugar damages per Gray of low LET radiation.

120. Historically for locally advanced breast cancer, what signs were associated with low likelihood of negative margins and high recurrence rates if patients proceeded directly to resection?
- A. Multicentric disease and nipple retraction
 - B. Extensive skin edema and satellite skin nodules
 - C. ER negativity and palpable mobile axillary nodes
 - D. Palpable breast mass and nipple discharge

Key: B

Citations:

Haagensen, CD and Stout, AP. Annals of Surgery. 1942 Dec: 116(6), 801-815.

Haagensen, CD and Stout, AP. Annals of Surgery. 1951 Dec: 118(6), 1032-1051.

Haagensen, CD and Stout, AP. Annals of Surgery. 1943 Dec: 118(6), 1032-1051.

Rationale: Haagensen and Stout published their surgical results in the treatment of advanced breast cancers and proposed criteria of operability based on the extent of carcinoma. The following features were among those considered as inoperable as radical resection was not likely to result in disease control or cure: extensive skin edema, skin satellite nodules, intercostal or parasternal nodules, arm edema at presentation, supraclavicular nodal disease, inflammatory breast cancer.

121. Which is a clinically significant (potential) advantage of proton therapy over x-ray therapy for patients with Hodgkin lymphoma?
- A. Lower risk of secondary malignancy
 - B. Ability to safely treat a smaller clinical target volume
 - C. Improved progression free survival
 - D. Faster daily treatment time

Key: A

Citations: Int J Radiat Oncol Biol Phys. Tseng et al. 2017 Nov 15. 99(4):825-842.

Rationale: Because a proton beam does not deliver dose distal to the Bragg peak, proton therapy inherently delivers less integral dose and reduced low dose to normal organs. This is expected to reduce the likelihood of late adverse effects including secondary malignancy.

122. When using brachytherapy alone for medically inoperable Stage I endometrial cancer, the ABS consensus statement recommends that the D90 of the CTV receive an EQD2 of at least
- A. 24 Gy
 - B. 32 Gy
 - C. 40 Gy
 - D. 48 Gy

Key: D

Citations: Consensus statement for brachytherapy for the treatment of medically inoperable endometrial cancer. Schwartz, 2015, 587-599, Brachytherapy 14.

Rationale: Based on best available evidence, the panel recommends that patients with Stage I endometrial cancer should receive an EQD2 of at least 48 Gy for brachytherapy alone and at least 65 Gy for the combination of EBRT + brachytherapy to 90% of the (D90)CTV volume encompassing the entire uterus, dependent on tumor and patient specific factors.

123. In the ACOSOG Z0011 study of axillary dissection (AxLND) vs. no AxLND in women with positive sentinel lymph nodes (SLN):
- A. less than 5% of patients did not receive protocol specified radiation treatment.
 - B. there was an imbalance of Her2+ patients between the arms favoring the SLN alone group.
 - C. nearly 30% of patients who underwent AxLND had additional lymph nodes containing macrometastases beyond the SLNs.
 - D. more patients on the AxLND arm received adjuvant chemotherapy due to the additional nodal disease found versus patients on the SLN alone arm.

Key: C

Citations: Giuliano AE, Ballman KV, McCall L, et al. , Effect of Axillary Dissection vs. No axillary Dissection on 10-year overall survival among women with invasive breast cancer and Sentinel node metastasis. The ACOSOG Z0011 (Alliance) Randomized clinical trial, JAMA, Sept 12, 2017, 918-926, 318(10).

Rationale: A: 18.9% of patients received protocol-prohibited nodal irradiation and 11% of patients did not receive radiation. B: The treatment groups were well balanced with respect to patient and disease characteristics including hormone receptor status. Her2 status was not reported. C: 27.3% of patients in the ALND group had macrometastases (>2mm) in nonsentinel lymph nodes removed during ALND. D: There was no difference in the type of chemotherapy or the proportion receiving endocrine therapy, chemotherapy or both among the two groups.

124. As per the ABS guidelines (Viswanathan,2012), what is the most common HDR brachytherapy prescription for cervical cancer with complete response to EBRT?
- A. 25 Gy in 5 fractions
 - B. 27.5 Gy in 5 fractions
 - C. 28 Gy in 4 fractions
 - D. 30 Gy in 5 fractions

Key: B

Citations: Brachytherapy. Viswanathan A 2012. 11(1), 47-52.

Rationale: The EQD2 of 27.5 Gy/5 fractions is approximately 80 Gy, which is considered adequate for tumors well responding to external beam irradiation. In order to maximize local control in tumors greater than 4 cm at the time of implant, dose range of 85-90 Gy is recommended.

125. In humans, thymine dimers are predominantly repaired by which process?
- A. Excision repair
 - B. Homologous recombination repair
 - C. Oxidative repair
 - D. Nonhomologous end joining

Key: A

Citations: Radiation Biology for the Radiologist Eric Hall and Amato Giaccia 2012. 17 Lippincott Williams Wilkins 7th edition.

Rationale: Thymine dimers are repaired by either (a) photoreactivation repair, where the PRE enzyme activated by blue light breaks the dimer, restoring the normal base pairing or (b) excision repair, in which the uvr system excises the dimer, and the gap is filled in by the proof-reading activity of DNAPol I.

126. For pure seminoma stage I patients on active surveillance following orchiectomy, what is the approximate rate of salvage at the time of recurrence?
- A. 80%
 - B. 85%
 - C. 90%
 - D. 95%

Key: D

Citations: Patterns of relapse in patients with clinical stage I testicular cancer managed with active surveillance. Kollmannsberger C, et.al. Jan 1, 2015; 51-7JCO33 (1).

Rationale: Stage I Seminoma has low rates of recurrence and a very high rates of successful salvage at recurrence, making active surveillance a good treatment options for compliant patients.

127. What is the most effective adjuvant chemotherapy regimen for resectable pancreatic cancer?
- A. FOLFOX
 - B. Gemcitabine/capecitabine
 - C. Gemcitabine/abraxane
 - D. FOLFIRINOX

Key: D

Rationale: PRODIGE 24/CCTG PA.6 was a randomized Phase III center of 493 patients evaluating the efficacy of modified FOLFIRINOX to gemcitabine after surgical resection. After a median follow-up of 30.5 months, multiple outcomes were significantly improved with modified -FOLFIRINOX vs gemcitabine (Table 1). Median disease-free survival was 12.8 months in the gemcitabine arm vs 21.6 months in the modified FOLFIRINOX arm, and median overall survival was 35.0 months vs 54.4 months, respectively.

128. According to the Radiation Effects Research Foundation (RERF) the most recent follow up (1958-2009) of the data from the life span study (LSS) of the Japanese atomic bomb survivors indicates what shape for the dose response for excess relative risk (ERR) of solid cancer incidence in males?
- A. Linear with no threshold
 - B. Linear with a threshold
 - C. Linear-quadratic with no threshold
 - D. Linear-quadratic with a threshold

Key: C

Citations: Radiat Res, 2017, 187:513-537.

Rationale: The most recent report on solid cancer incidence (see reference) revealed significant upward curvature for males. This is contrary to previous reports and what the data displayed for females. While this change is strongly supported by the data, RERF is uncertain how to respond in terms of making recommendations for radiation protection considerations. They suggest that upcoming analyses on specific organs and organ families as well as additional follow up are “needed to fully understand the nature of radiation-related cancer risk and its public health significance”.

129. What is the cell-loss factor for all human tumors?
- A. <10%
 - B. 10-15%
 - C. 20-40%
 - D. >50%

Key: D

Citations: Radiation Biology for the Radiologist. Eric Hall and Amato Giaccia 2012. 382-3, 388 Lippincott Williams Wilkins 7th edition.

Rationale: Cell-loss factor represents the ratio of rate of cell loss to the rate of new cell production. Values for the cell-factor factor vary from 0% to 90%. Tubiana and Malaise have estimated an average value for a range of human tumor to be in excess of 50% and Steel has estimated a median value of 77% for all human tumors studied.

130. What was the approximate 10-year local control rate following RT for aggressive fibromatosis?
- A. 40%
 - B. 50%
 - C. 80%
 - D. 95%

Key: C

Citations: Bates et al., IJROBP, 2017:100(4), 997-1003.

Rationale: For patients with aggressive fibromatosis, radiation can provide excellent local control. Authors from the University of Florida reported a series of 101 patients treated with RT from 1975-2015. While there was variation over the years, usual RT dose was 50-55Gy using 3-5 cm margins. With a median follow up 14.3 years, overall survival and local control were excellent (OS: 98% and 95% and LC: 82% and 78% at 5 and 10 years, respectively). Younger had significantly worse local control following RT compared with patients aged >40 yrs at diagnosis.

131. A 60-year old patient presents with a stage I lymphoma involving mucosa-associated lymphoid tissue (MALT) of the left parotid gland. What is a reasonable standard prescription dose for definitive RT?
- A. 24 Gy
 - B. 36 Gy
 - C. 45 Gy
 - D. 50.4 Gy

Key: A

Citations: NCCN Clinical Practice Guidelines in Oncology, NCCN Guidelines, Non-Hodgkin Lymphoma Version 1.2018.

Rationale: Refer to NCCN Guidelines.

132. In a secondary analysis of RTOG 0617, which factor was NOT statistically significantly associated with \geq grade 3 pneumonitis on multivariate analysis?
- A. Lung V5
 - B. Stage IIIB disease
 - C. Lung V20
 - D. 3D (vs. IMRT)

Key: A

Citations: Journal of Clinical Oncology Chun et al. 56-62.

Rationale: Chun et al. in a secondary analysis demonstrated that for grade 3+ pneumonitis, IMRT vs. 3D decreased risk of pneumonitis (OR 0.41, P=0.046) whereas IIIB disease (OR 2.28, P=0.048) and Lung V20 (OR 1.07, P=0.026) both increased risk. PTV, lung V5, and mean lung dose were not statistically significant (P>0.05).

133. For a point 1 cm away from a ²²⁶Ra source, the exposure rate ratio of a point source to a linear source is:
- A. < 1.
 - B. 1.
 - C. > 1.
 - D. 0.

Key: C

Citations: The physics of radiation therapy, Faiz M. Khan, 2010, 327, Lippincott Williams Wilkins, 4th edition.

Rationale: Linear source suffers from oblique filtration and travel larger distance than point source. Hence the ratio of the exposure rate of a point to that of a linear source is > 1.

134. A study is conducted to evaluate the accuracy of an X-ray examination. The investigators consider pathological results as the correct diagnosis. The relationship between the results of two diagnosis methods is shown below. What is the specificity of the X-ray?

X-Ray Pathology

Abnormal	Abnormal	300
Abnormal	Normal	30
Normal	Abnormal	20
Normal	Normal	150

- A. 62.5%
- B. 83.3%
- C. 90.91%
- D. 93.75%

Key: A

Citations: M.P.H. Judith S. Mausner, Shira Kramer, Mausner and Bahn Epidemiology: An Introductory Text, 1985, Chapter 11, W. B. Saunders Company, 2nd edition.

Rationale: The sensitivity and specificity are also used in investigating the performance of simpler diagnostic tests. Suppose “gold standard” tests provide whether or not a subject actually has the disease. The number of subjects without disease based on the “gold standard” diagnosis is 30+150. Among those 150 subjects are classified as not having disease by X-ray examination: Specificity= $150 / (150+30) = 62.5\%$.

135. The “goodness-of-fit” of a measured data set to an expected distribution of the data is given by which of the following?
- A. Hazard ratio
 - B. Wilcoxon rank sum test
 - C. Specificity
 - D. Chi-squared test

Key: D

Citations: Basic and Clinical Biostatistics, Dawson B and Trapp RG, 2004, pp 149-152, McGraw-Hill, 4th edition.

Rationale: The Chi-squared test compares the measured number of observations of a quantity to the expected number of observations based on an assumed distribution or hypothesized distribution. It can be defined as a statistical test used to test the null hypothesis that proportions are equal or, equivalently, that factors or characteristics are independent or not associated.

136. Which statement is TRUE regarding the recent 2018 ASTRO guideline on fractionation for WBI?
- A. The use of hypofractionation in patients < 40 years of age should be avoided
 - B. The use of adjuvant chemotherapy should not affect the decision regarding fractionation
 - C. For patients in whom the inclusion of the low axilla is intended, conventional fractionation is preferred
 - D. The guideline applies to early stage invasive breast cancer and not DCIS

Key: B

Citations: Smith BD, Bellon JR, Blitzblau R, et al., Radiation therapy for the whole breast: Executive summary of an ASTRO evidence-based guideline., Practical Radiation Oncology, Vol 8, May-June 2018, 148.

Rationale: In table 1, page 148, the 2018 guideline stated that the panel supports the use of hypofractionation in patients of any age in whom the intent is to treat the whole breast without additional fields to cover regional lymph nodes and applies to both invasive cancer and DCIS. Use of adjuvant chemotherapy is not an exclusion for use of hypofractionation.

137. Using modern chemotherapy regimens, which molecular subtype is associated with the highest rates of pCR after neoadjuvant chemotherapy?
- A. Hormone receptor HR (+) / Her-2 (-)
 - B. Hormone receptor HR (+) / Her-2 (+)
 - C. Hormone receptor HR (-) / Her-2 (-)
 - D. Hormone receptor HR (-) / Her-2 (+)

Key: D

Citations: Swisher SK, Vila J, Tucker SL et al, Locoregional Control According to Breast Cancer Subtype and Response to Neoadjuvant Chemotherapy in Patients Undergoing Breast-conserving Therapy, *Ann Surg Oncology*, March 2016, 749-56, 23(3).

Rationale: In the publication by Swisher et al the pCR rates following neoadjuvant chemotherapy for the different subgroups were as follows:

HR (+)/Her-2(-) – 16.5%

HR (+)/Her-2 (+) – 45.7%

HR (-)/Her-2 (-) – 42%

HR (-)/Her-2(+) – 72.4%

138. If the energy of an electron beam is increased for a treatment, what happens to the skin dose?
- A. Increases
 - B. Decreases
 - C. Stays the same
 - D. Depends on the energies used

Key: A

Citations: *The Physics of Radiation Therapy*, Khan, 2010, 310 – Fig 14.11, Lippincott, Williams Wilkins, 4th.

Rationale: Unlike photon beams, the surface dose from electron beams increase with increasing energy.

139. A patient with metastatic NSCLC with four sites of bony metastasis, which of the following describes an appropriate management strategy?
- A. Nivolumab as first line therapy if the PD-L1 status is 1%
 - B. Erlotinib as first line therapy if the patient has EGFR T790M mutation
 - C. SBRT upfront to treat the bony metastasis followed by chemoradiation for the primary disease
 - D. Platinum-based 2-drug combination therapy with pembrolizumab if the PD-L1 status is 30%

Key: D

Citations: NEJM. Gandhi L et al. May 31, 2018; 2078-2092.

Rationale: A is incorrect because Nivolumab is not given as first line for any PD-L1 status. B is incorrect because osimertinib is the first line for T790M mutant NSCLC. C is incorrect because SBRT and chemoradiation is not the standard approach. Patients with metastatic NSCLC needs to be evaluated for targeted therapy or immunotherapy options first line. For those with oligometastatic disease ongoing trials are exploring the use of SBRT/Sx and hypofractionated RT for consolidation after systemic therapy. Chemoradiation followed by SBRT to limited metastatic disease could be considered in select cases with limited metastatic disease. D is correct because Keynote 189 demonstrated improve OS and PFS in patients who received the combination of chemotherapy and pembrolizumab vs. chemotherapy alone, regardless of the PD-L1 status.

140. Which is now the MOST common presentation of renal cell carcinoma?
- A. Gross hematuria, flank mass, and pain
 - B. Erythrocytosis
 - C. Discovered incidentally on imaging
 - D. Hypercalcemia

Key: C

Citations: Cancer. Volpe et al. 2004 Feb 15. 100(4):738-45.

Rationale: Largely due to the widespread use of cross-sectional imaging, most renal tumors (48% to 66% of tumors <4cm) are detected incidentally as small, asymptomatic masses. The classic triad of gross hematuria, flank mass, and pain occurs in only 5 – 10% of patients and usually indicates advanced disease. However, at least one of these symptoms may be found in 40% of patients. Erythrocytosis can be seen as a paraneoplastic syndrome due to the elaboration of erythropoietin. Hypercalcemia can occur in 25% of patients with metastatic disease.

141. The rapid phosphorylation of PERK and which other protein regulate the kinetics of mRNA translation and protein synthesis of HIF-1 α ?
- A. mTOR
 - B. GTP
 - C. XBP-1
 - D. eIF2 α

Key: D

Citations: Mol Cancer Res. Koumenis and Wouters. 2006. 423-436.
Radiobiology for the Radiologist, Seventh ed. Hall and Giaccia.

Rationale: The stability and activity of HIF-1 α is regulated not only by the absolute level of oxygenation but also by the length of hypoxic exposure. The selective degradation of HIF-1 α under aerobic conditions occurs due to modification of two proline residues in its oxygen-dependent degradation domain, by one of a family of prolyl hydroxylase enzymes 1 to 3. The prolyl hydroxylase enzymes are themselves targets of HIF, leading to the establishment of a negative feedback loop and an increased rate of HIF degradation during continued hypoxia.

142. What was revealed in a recently completed phase III study (JCO 2017) in patients with intermediate risk prostate cancer comparing 78 Gy in 39 fractions vs. 60 Gy in 20 fractions?
- A. A higher rate of grade \geq 3 late genitourinary toxicity in the 60 Gy arm
 - B. A higher rate of grade \geq 3 late gastrointestinal toxicity in the 60 Gy arm
 - C. No difference in grade \geq 3 late toxicities between 60 Gy and 78 Gy
 - D. Improved disease-free survival in the 60 Gy arm

Key: C

Citations: Randomized Trial of a Hypofractionated Radiation Regimen for the Treatment of Localized Prostate Cancer. Catton CN, Lukka H, Gu CS, Martin JM, Supiot S, Chung PWM, Bauman GS, Bahary JP, Ahmed S, Cheung P, Tai KH, Wu JS, Parliament MB, Tsakiridis T, Corbett TB, Tang C, Dayes IS, Warde P, Craig TK, Julian JA, Levine MN. 2017 Jun 10. J Clin Oncol.

Rationale: This randomized trial had a 5-year disease free survival of 85% in both arms. Furthermore, no significant differences were detected between arms for grade \geq 3 late toxicities. 60 Gy in 20 fractions is now one of the hypo-fractionated prostate cancer radiation dose regimens endorsed by the NCCN.

143. Which is the MOST efficient SBRT radiation delivery technique in terms of total treatment time when accounting for respiratory motion?
- A. Robotic MLC tracking
 - B. Free-breathing gating (20% gating window)
 - C. Inspiration/Exhalation breath-hold method
 - D. Abdominal compression with ITV method

Key: D

Citations: The management of respiratory motion in radiation oncology, Keall P et al. 2006, 3874-3900, Medical Physics, Vol 33 (10).

Rationale: For the same dose and approximately the same target, abdominal compression with ITV method would be the most efficient in delivery due to the 100% beam-on time.

144. When using MRI- based brachytherapy for the treatment of cervical cancer, GEC-ESTRO defines the high risk clinical target volume (HR-CTV-B) as the gross tumor volume based on examination and the:
- A. entire cervix.
 - B. T2 signal intensity on MRI.
 - C. entire cervix and gray zones on MRI T2 sequences.
 - D. entire cervix and MRI T2 sequences, and 15 mm margin.

Key: C

Citations: Image-Based Brachytherapy for the Treatment of Cervical Cancer. Harkenrider, 2015, 921-934. IJROBP, Vol 90, Number 4.

Rationale: GTV is the gross tumor volume at time of brachytherapy based on visualization and palpation and the T2 signal on MRI. HR-CTV-B is the high risk clinical target volume at brachytherapy and includes the GTV, entire cervix, and gray zones on MRI T2 sequences. IR-CTV is the intermediate-risk clinical target volume includes 5 to 15 mm margin around HR-CTV and includes initial sites of involvement.

145. An early SBRT institutional experience demonstrated high rates of grade 3-5 airway toxicity when 60-66 Gy in 3 fractions was delivered to central tumors. How was the extent of this “central tumor region” defined for subsequent SBRT studies?
- A. Tumors touching the lobar bronchi
 - B. Tumors within 1 cm of the sub-lobar bronchi
 - C. Tumors within 3 cm of the trachea
 - D. Tumors within 2 cm of the lobar bronchi

Key: D

Citations: J Clin Oncol Timmerman R. Oct 20 2006; 4833.

Rationale: Figure 3 from the Timmerman et al study defines the “zone of the proximal bronchial tree” which was used as inclusion criteria for subsequent central SBRT studies such as RTOG 0813. This diagram defines this region as within 2 cm of the trachea, mainstem bronchi, or most distally the lobar bronchi.

146. What is a CONTRAINDICATION to bladder preservation therapy with chemoRT in the treatment of bladder cancer?
- A. T2 tumor on cystoscopy
 - B. Maximal TURBT cannot be performed
 - C. Tumor located on the lateral bladder wall
 - D. Tumor size of 4 cm on cystoscopy

Key: B

Citations: NCCN Guidelines Version 1. 2018 – Bladder Cancer.

Rationale: In patients who undergo a bladder conservation approach, maximal transurethral resection of the tumor should occur before proceeding with chemoradiation.

147. Which of the following options describe the best management strategy for SCLC by AJCC stage grouping?
- A. Stage I SCLC- Lobectomy and adjuvant chemotherapy followed by consideration of PCI
 - B. Stage II SCLC- Chemoradiation and consolidation durvalumab with no PCI
 - C. Stage III SCLC- Chemoradiation therapy followed by lobectomy and PCI
 - D. Stage IV SCLC- Chemotherapy followed by consolidation thoracic RT to 45 Gy in 15 fractions and PCI

Key: A

Citations: NCCN 2018 guidelines.

Rationale: A is the correct response. Patients with stage I SCLC is better managed with lobectomy and adjuvant chemotherapy. PCI should be considered as well. B is incorrect since locally advanced SCLC needs chemoradiation, chemotherapy and PCI. Durvalumab is currently approved for unresectable NSCLC undergoing chemoradiation. For extensive stage patients PCI could be deferred if using MRI surveillance but for LS-SCLC, PCI is strongly recommended. C is incorrect since neoadjuvant chemoradiation is not used on SCLC but could be considered for selected locally advanced NSCLC. D is incorrect because 45 Gy in 15 fractions consolidation is deemed unsafe, and 30 Gy in 10 fractions is the standard of care.

148. What is the purpose of the dummy wire in an ^{192}Ir HDR remote afterloader unit?
- A. To confirm that the correct patient is being treated
 - B. To confirm that the path the radioactive source travels is clear of obstruction
 - C. To measure the activity of the radioactive source along the path of travel
 - D. To measure the dwell time accuracy of the radioactive source

Key: B

Citations: Practical Radiation Oncology, Physics, Sonja Dieterich, 2016, 115, Elsevier, 1st edition.

Rationale: The dummy wire is sent out before the radioactive wire. This is to confirm that the path of travel is clear from obstruction before treatment commences with the radioactive wire.

149. On the AREN0534 trial, what was the 4 year EFS for patients with bilateral Wilms tumor?

- A. 22%
- B. 42%
- C. 62%
- D. 82%

Key: D

Citations: Breslow N. 2005. End stage renal failure in patients with Wilms tumor: results from the national Wilms tumor study group and the United States renal data system. 1972-1975. Elsevier.

Kieran K. 2015. Nephron-sparing surgery for bilateral Wilms tumor. 229-236. Springer Link.

Ehrlich P. 2017. Results of the First Prospective Multi-institutional Treatment Study in Children With Bilateral Wilms Tumor (AREN0534): A Report From the Children's Oncology Group. 470-478. Wolters Kluwer Health.

Rationale: Patients with bilateral Wilms tumor are at high risk for end-stage renal disease and this rate can be substantially higher in patients with genetic syndromes. While event free survival on the historical NWTS 4 and 5 studies was poor for bilateral Wilms tumor, the recently completed AREN0534 protocol surpassed the protocol specified goal of a 4-year EFS of 75% and obtained a 4-year event free survival of 82%. Neoadjuvant chemotherapy is uncommonly used for Wilms tumor in the US but is frequently utilized by the SIOP group for many stages of Wilms tumor. While Davidoff et al found that nephron sparing surgery could be performed in as much as 92%, AREN0534 documented that this finding was not generalizable to the multicentre setting as nephron sparing surgery was only able to be achieved in ~40% of patients.

150. Rather than reporting the maximum point dose for an OAR, ICRU 83 recommends reporting the near maximum dose as which measure?

- A. D98%
- B. D2%
- C. D100%
- D. D50%

Key: B

Citations:

ICRU Report 83: Prescribing, Recoding, and Reporting Photon-Beam Intensity Modulated Radiation Therapy (IMRT), ICRU, 2010, 6, ICRU.

The Physics and Technology of Radiation Therapy, McDermott Orton, 2010, Medical Physics Publishing, 1st edition.

151. What is the approximate minimum energy to produce an ionizing event?
- A. 4.9 eV
 - B. 25 eV
 - C. 10 keV
 - D. 100 keV

Key: B

Citations: Radiobiology for the Radiologist, Hall and Giaccia, 2012, 358-359 Chapter 17th edition, Lippincott, Williams and Wilkins.

Rationale: Since different molecules and atoms ionize at different energies, the boundary of ionization is between 10 eV and 33 eV. 4.9eV is the energy required to break a C=C bond, 100keV is the energy required for Compton scattering and 10keV is associated with photoelectric absorption.

152. Which cell cycle phases has the greatest impact on the length of the cell cycle?
- A. G1
 - B. G2
 - C. S
 - D. M

Key: A

Citations: Radiation Biology for the Radiologist Eric Hall and Amato Giaccia 2012. 381-2 Lippincott Williams Wilkins 7th edition.

Rationale: G1 can vary from less than 1 hour to greater than 1 week, and thus has the greatest impact on cell cycle times. G2 and M are generally short (<2h) and S phase varies but is typically less than 10 hours.

153. I-SPY trial is a trial in which experimental agents are tested against control treatment in a neoadjuvant setting with a primary outcome of pathologic complete response. There are 8 randomization subgroups defined by biomarkers, and randomization within strata is adjusted at predefined accruals and follow-up to increase the likelihood of assignment to a given therapy as evidence accrues that it is more efficacious than control. This trial is an example of which of the following clinical trial designs?

- A. Accelerated titration phase I
- B. Phase I/II trial
- C. Adaptive randomized phase II
- D. Phase III trial

Key: C

Citations: Adaptive Clinical Trials: Advantages and Disadvantages of Various Adaptive Design Elements, Korn and Freidlin, Jun 1, 2017; 109 (6), J Natl cancer Inst.

154. In the 2016 WHO Classification of Tumors of the CNS, an H3 K27M-mutant midline glioma includes the tumor formerly known as:

- A. ependymoblastoma.
- B. subependymal giant cell astrocytoma.
- C. oligoastrocytoma.
- D. diffuse intrinsic pontine glioma.

Key: D

Citations:

Journal of Clinical Oncology. Sturm, Dominik. 2017 June 22. 35 (21): 2370–77.
Acta Neuropathologica. Louis, David N. 2016 June. 131 (6): 803–20.

Rationale: In the 2016 WHO Classification of Tumors of the CNS, the tumor formerly known as diffuse intrinsic pontine glioma (DIPG), is now classified as ‘diffuse midline glioma, H3 K27M-mutant’. These diffuse, midline tumors are characterized by K27M mutations in the histone H3 gene and occur in pediatrics and adults in midline locations (e.g., thalamus, brain stem, and spinal cord). Oligoastrocytomas largely no longer exist in the molecular era, based on their 1p19q deletion status (co-deleted, IDH mt tumors are oligodendrogliomas; non-codeleted, IDH mt tumors are astrocytomas). Ependymoblastoma is now classified as an ETANTR (embryonal tumor with abundant neuropil and true rosettes).

155. What is MOST predictive for occult lymph node metastasis from floor of mouth SCC?

- A. Size
- B. Grade
- C. Location
- D. Tumor thickness

Key: D

Citations: Mohit-Tabatabai, et al. 1986 Oct. 351-353. Am J Surg. 152(4). Prognostic factors of clinically stage I and II oral tongue carcinoma-A comparative study of stage, thickness, shape, growth pattern, invasive front malignancy grading, Martinez-Gimeno score, and pathologic features.
Shah. 2002 Jun. 513-20. Head Neck. 24(6), Relation of thickness of floor of mouth stage I and II cancer to regional metastasis.

Rationale: Tumor thickness is the most important prognostic factor in regards to the risk of nodal spread and elective treatment of a clinically-negative neck is recommended when the tumor thickness exceeds 2 mm since the risk of occult disease is greater than 15%. The AJCC 8th edition staging manual has been modified to take into account depth of invasion for T staging.

156. In the SMART trial, a randomized study comparing immediate versus deferred radiotherapy to reduce the incidence of procedure-tract metastases (PTMs) in patients with malignant pleural mesothelioma it was noted that,

- A. use of immediate radiotherapy reduces occurrence of PTMs.
- B. RT dose for both cohorts was 21 Gy in 3 fractions.
- C. use of immediate radiotherapy provided improved symptom control.
- D. overall incidence of PTM in this population is about 30-40%.

Key: B

Citations: Lancet Oncol 2016. Clive et al.2016 Aug 17(8):1094-1104.

Rationale: The SMART trial was a multicentre, open-label, phase 3 randomised controlled trial that tested if r immediate radiotherapy given within 42 days of a large-bore pleural intervention reduces the incidence of PTMs developing in mesothelioma, compared with deferred radiotherapy delivered only when PTMs develop. The study included patients who had undergone (in the previous 35 days) an open pleural biopsy, surgical thoracotomy or video-assisted thoracoscopic surgery, local anaesthetic thoracoscopy, large-bore chest tube insertion (≥ 20 French [Fr], or an indwelling pleural catheter insertion. RT dose in both groups was 21 Gy in 3 fractions. No significant difference was seen in PTM incidence in the immediate and deferred radiotherapy groups (nine [9%] vs 16 [16%]; odds ratio 0.51 [95% CI 0.19-1.32]; $p=0.14$). Further, immediate RT did not result in benefits in terms of symptom control, analgesia use, survival, or quality of life. As such, routine use of prophylactic radiotherapy in all patients with mesothelioma after large-bore thoracic interventions is not justified. In a sub-group analysis of per-protocol RT, there was reduction in the incidence of PTM. But given the lack of any benefit in the patient-centered outcomes and overall low rate of occurrence of symptomatic PTM, active surveillance strategy was felt to be preferable.

157. Where is the primary motor cortex in the brain?

- A. Frontal lobe anterior to the central sulcus
- B. Frontal lobe posterior to the central sulcus
- C. Parietal lobe anterior to the central sulcus
- D. Parietal lobe posterior to the central sulcus

Key: A

Citations: Neurosurgical Focus. Ribas, Guilherme Carvalhal. 2010 Feb. 28 (2): E2.

Rationale: The primary motor cortex is in the precentral gyrus of the frontal lobe, immediately anterior to the central sulcus. The postcentral gyrus, posterior to the central sulcus, is the sensory cortex in the parietal lobe.

158. Regarding TIME-C (RTOG 1203) and RTOG 0724 trials for gynecologic malignancies, what is the recommended small bowel dose constraint when treating with adjuvant pelvic IMRT?

- A. V40 < 10%
- B. V40 < 20%
- C. V40 < 30%
- D. V40 < 40%

Key: C

Citations: Klopp A, Yeung A, Gil K, et al. 3-16-2015. NRG Oncology 1-79. RTOG 1203 a randomized phase III study of standard vs. IMRT pelvic radiation for post-operative treatment of endometrial and cervical cancer (time-c). Jhingran A, Gray H, Weidhaas J, et al. 12-29-2010. RTOG 1-72. RTOG 0724/GOG-0724 phase III randomized study of concurrent chemotherapy and pelvic radiation therapy with or without adjuvant chemotherapy in high-risk patients with early-stage cervical carcinoma following radical hysterectomy.

Rationale: This dose constraint is the only small bowel constraint utilized in the TIME-C (RTOG 1203) and RTOG 0724 trials utilizing IMRT for pelvic radiation therapy after hysterectomy.

159. How is the radiosensitivity of the jejunum quantified?
- A. Number of regenerating crypts
 - B. Number of shortened villi
 - C. Density of cells in the surface membrane
 - D. Density of cells in the inner membrane

Key: A

Citations:

The clonogen content of murine intestinal crypts: dependence on radiation dose used in its determination. Hendry JH, Roberts SA, Potten CS. 1992. 115-119. Radiation Research.
Regeneration of intestinal mucosa after irradiation. Withers. 1971. 7-81 Cancer.

Rationale: In the small intestine one of the first effects within the epithelium after irradiation is that of stem cell apoptosis, evident within a few hours of even low-dose irradiation. Stem cell death will not produce GI acute radiation syndrome unless the dose is sufficiently large to eliminate all the stem cells, such that there is no regeneration of the tissue and therefore tissue function is lost. For GI syndrome, this requires death of the extended clonogenic cell populations. A hierarchical response to radiation has been proposed within the clonogenic cell population, with increasing doses of radiation targeting successive tiers of clonogens within each intestinal crypt. The score of radiation damage is therefore determined by assessing the number of regenerating crypts per circumference of the sectioned jejunum. The number of crypts is plotted against as a function of dose to determine clonogenic survival. Wither. Cancer 28:78-81, 1971.

160. What percent of oropharyngeal cancers in the United States are currently caused by HPV?
- A. <20%
 - B. 20-30%
 - C. 40-50%
 - D. >60%

Key: D

Citations: Prevalence of Human Papillomavirus in Oropharyngeal Cancer: A Systematic Review. Stein AP, Saha S, Kraninger JL, et al. The Cancer Journal 2015, 21(3):138-46.
Human papillomavirus and rising oropharyngeal cancer incidence in the United States. Chaturvedi AK, Engels EA, Pfeiffer RM, et al. Journal of Clinical Oncology 2011; 29(32):4294–4301.

Rationale: HPV is now the major cause of oropharyngeal cancer in the United States. The incidence has increased significantly over the last 20 years.

161. Errors in which of the following DNA Repair pathways results in Xeroderma Pigmentosum?
- A. Base Excision Repair
 - B. Nucleotide Excision Repair
 - C. DNA Double-Strand Break Repair
 - D. Nonhomologous End-Joining

Key: B

Citations: Radiation Biology for the Radiologist. Eric Hall and Amato Giaccia 2012. 17 Lippincott Williams Wilkins 7th edition.

Rationale: Xeroderma Pigmentosum, an autosomal recessive disorder, is characterized by impaired nucleotide excision repair. There have been at least 9 mutations identified with 7 complementation groups and 1 variant with varied expression of severity of disease.

162. According to the 2017 ASTRO guideline update on palliative RT for bone metastases, what fractionation schemes were shown to have pain relief equivalency in the treatment of previously unirradiated painful peripheral bone metastases?
- A. 8Gy in 1 fraction, 20Gy in 4 fractions, and 24Gy in 6 fractions
 - B. 8Gy in 1 fraction, 20Gy in 4 fractions, and 30Gy in 10 fractions
 - C. 8Gy in 1 fraction, 20Gy in 5 fractions, and 30Gy in 10 fractions
 - D. 8Gy in 1 fraction, 20Gy in 5 fractions, and 37.5Gy in 15 fractions

Key: C

Citations: "Palliative radiation therapy for bone metastases: Update of an ASTRO Evidence-Based Guideline." PRO Lutz et al. 2017, 7. 4-12.

Rationale: Per the ASTRO evidence-based guideline update: 8Gy in 1 fraction, 20Gy in 5 fractions, 24Gy in 6 fractions, and 30Gy in 10 fractions showed pain relief equivalency. Single fraction treatment was associated with a higher incidence of retreatment than the other fractionated regimens.

163. In a phase II trial of proton irradiation for liver metastases (Hong et al, JNCI 2017), local failure was highest in tumors that were:
- A. KRAS mutant.
 - B. KRAS wild-type.
 - C. > 6 cm diameter.
 - D. treated with 30-40 Gy to the GTV.

Key: A

Citations: Hong et al., 2017. Phase II Study of Proton-Based Stereotactic Body Radiation Therapy for Liver Metastases: Importance of Tumor Genotype. J Natl Cancer Inst.

Rationale: In a single-arm phase II single institutional study in patients with limited extrahepatic disease, 800 mL or greater of uninvolved liver, and no cirrhosis or Child-Pugh A, who had received proton-based SBRT to one to four liver metastases from solid tumors, colorectal tumors had higher failure rates than other non-colorectal adenocarcinomas. The study also observed that oncogenic mutations in KRAS were the strongest predictor of local failure (one-year LC 42.9% with mutation versus 72.1% without mutation). Multivariable testing revealed that the combination of mutated KRAS with hotspot mutations in the TP53 tumor suppressor define a subset of extremely radioresistant tumors. When comparing tumors > or < 6 cm diameter, there was no difference in local control. There was no difference in local control in patients who received 50 GyE to the GTV versus 30-40 GyE (77.4% vs 69%, respectively).

164. To account for heterogeneities during proton treatment planning, the CT numbers of a planning CT dataset need to be converted to:
- A. relative linear attenuation coefficient.
 - B. relative mass attenuation coefficient.
 - C. relative mass density.
 - D. relative stopping power ratios.

Key: D

Citations: Practical Radiation Oncology Physics, Dieterich S et al, 2016, Chapter 9, Elsevier, 1st edition.

Rationale: For proton treatment planning, the CT numbers of the planning CT need to be converted to the relative stopping power ratio. Photon dose calculations require the relative linear attenuation coefficient.

165. What translocation or chromosomal aberration is associated with a failure of antibiotic therapy for H.pyloric eradication for Gastric MALT?
- A. t(10;14)
 - B. t(11;18)
 - C. chromosomal hyperdiploidy
 - D. t(9;22)

Key: B

Citations: Principles and Practice of Radiation Oncology, Perez Bradys.

Rationale: The presence of translocation t(11:18) is a feature associated with poor response to H. pylori eradication for gastric MALT. All others are not related to gastric MALT.

166. What LINAC output mode requires the highest electron gun current to produce the same dose rate at isocenter?
- A. 6 MeV electrons
 - B. 18 MeV electrons
 - C. 6 MV photons
 - D. 18 MV photons

Key: C

Citations: Introduction to Radiological Physics and Dosimetry, Attix, 1986, 210, Wiley.
Medical Electron Accelerators, Karzmark, Nunan, Tanabe, 1992, 140, McGraw Hill.

Rationale: Due to the relative inefficiency of bremsstrahlung production, a photon output mode requires orders of magnitude more beam current on a target to produce the same dose rate as an electron beam. Since bremsstrahlung production efficiency increases with energy, operating at 6 MV requires more beam current than 18 MV to produce the same dose rate.

167. In SRS, the half prescription isodose volume divided by the prescription isodose volume is the:
- A. Gradient Index.
 - B. Conformity Index.
 - C. Homogeneity Index.
 - D. New Conformity Index.

Key: A

Citations: J. Neurosurg. Paddick, Ian and Bodo Lippitz. 2006 Dec. 105: 8.

Rationale: The Gradient Index (GI) is the half prescription isodose volume divided by the prescription isodose volume. For example, for a plan prescribed to 20 Gy, the GI is the 10 Gy volume divided by the 20 Gy volume. Typically, the GI is less than 3.0. The conformity index (CI) is the prescription isodose volume divided by the tumor volume. The homogeneity index (HI) is the maximum dose divided by the prescription dose.

168. In the CATNON trial for anaplastic astrocytomas, the interim analysis (van den Bent, et al., Lancet 2017) found that:
- A. adjuvant temozolomide improved OS.
 - B. concurrent temozolomide improved OS.
 - C. adjuvant and concurrent temozolomide had the best OS.
 - D. chemotherapy did not improve OS.

Key: A

Citations: The Lancet. Bent, Martin J van den. 2017 Oct. 390 (10103): 1645–53.

Rationale: In the CATNON trial, patients with grade 3 non-codeleted gliomas (i.e., anaplastic astrocytomas) were randomized to 4 arms (1. radiotherapy (RT) to 59.4 Gy, 2. RT + adjuvant temozolomide (TMZ), 3. RT + concurrent TMZ, 4. RT + concurrent and adjuvant TMZ). The planned interim analysis found improved overall survival (OS) in the 2 adjuvant TMZ arms compared to the 2 arms without adjuvant TMZ: the hazard ratio for OS with TMZ was 0.65, with a 5-year OS of 56% with and 44% without adjuvant TMZ. Importantly, no data are yet available to determine if concurrent TMZ is of benefit.

169. Regarding sublethal damage repair (SLDR) and mammalian cell survival:

- A. a D0 of 10 Gy indicates a high capacity for SLDR.
- B. high temperatures > 50oC enhances SLDR.
- C. SLDR is independent of radiation LET.
- D. SLDR repair is complete with 5 minutes.

Key: A

Citations: Radiobiology for the Radiologist, Seventh ed. Hall and Giaccia, p 72.

Rationale: The shoulder region of the cell survival curve represents sublethal damage repair, and that is related to the beta component of cell kill. High temperatures over 50C would enhance cell kill, as would exposing cells to High LET radiations vs low. SLDR is generally complete by 1-2 hours, not 5 minutes. A D0 of 10 Gy would indicate the cell has high capacity for SLDR

170. When is radiation therapy delivered to a patient with high risk neuroblastoma?

- A. Prior to any chemotherapy
- B. After initial chemotherapy with Cisplatin, Cyclophosphamide, Doxorubicin, Etoposide, Topotecan, and Vincristine
- C. After myeloablative chemotherapy with autologous stem cell transplant
- D. After immunotherapy

Key: C

Citations: Advances in Risk Classification and Treatment Strategies for NeuroblastomaPinto NR, Applebaum MA, Volchenboum SL, Matthay KK, London WB, Ambros PF, Nakagawara A, Berthold F, Schleiermacher G, Park JR, Valteau-Couanet D, Pearson AD, Cohn SLSept 20, 2015. 3008-17 Journal of Clinical Oncology.

Rationale: The appropriate sequence of therapy is biopsy, induction chemotherapy with 6 agents, surgery, (possibly another cycle of chemotherapy), consolidative myeloablative chemotherapy with autologous stem cell transplant, radiation therapy, and immunotherapy.

171. What is the approximate 10-year local recurrence rate for small, low grade extremity soft tissue sarcomas following R0 resection?
- A. 2%
 - B. 10%
 - C. 20%
 - D. 35%

Key: B

Citations: Pisters PW. Long-term results of prospective trial of surgery alone with selective use of radiation for patients with T1 extremity and trunk soft tissue sarcomas, *Ann Surg*, 2007 Oct; 246(4):675-81; discussion 681-2.

Rationale: Select small, low grade STS tumors with negative margins may be managed with surgery alone. In the surgery-alone arm, the cumulative incidence rates of local recurrence at 10 years was 10.6% and sarcoma-specific death rate was 3.2%. All the isolated local recurrences (5 patients) observed in arm with negative margins (R0) were high grade tumors, suggesting that radiation may be omitted in selected patients with small (T1), low grade tumors with negative margins.

172. When data are plotted on a log-log scale, the slopes of the isoeffect curves for early responding tumors and tissue compared to late responding tissues are:
- A. shallower.
 - B. steeper.
 - C. comparable.
 - D. flat.

Key: A

Citations: Radiobiology for the radiologist Eric Hall, Amato Giaccia 2012, 395 Lippincott Williams and Wilkins 7th edition.

Rationale: In a log- log scale, the log of the dose to cause a certain isoeffect is plotted as a function of a log of the dose per fraction. The late responding tissues are typically steeper, whereas the early responding tissues and tumors are shallower.

173. What Reese Ellsworth Stage for retinoblastoma is plaque brachytherapy typically used?
- A. Stage II with progressive disease after non-irradiative focal therapy
 - B. Stage III with residual disease after chemotherapy
 - C. Stage III with residual disease and consolidative chemotherapy.
 - D. Stage II with a positive margin at the optic nerve after enucleation.

Key: A

Citations: Lucas JT Jr. 2018 Prior non-irradiative focal therapies do not compromise the efficacy of delayed episcleral plaque brachytherapy in retinoblastoma. BMJ Publishing PMID: 29954786.

Rationale: Other focal non-irradiative therapies are typically encouraged prior to the use of episcleral plaque brachytherapy even in patients with residual disease. Episcleral plaque brachytherapy is typically reserved for patients with progressive disease.

174. In the Prostate Testing for Cancer and Treatment (ProtecT) trial (NEJM 2016) that randomized men with localized prostate cancer to active monitoring, radiotherapy, or surgery, what was reported?
- A. No significant difference of survival at 10 years between the radiation and surgery arms
 - B. The observation arm reported statically significant increases in anxiety
 - C. Prostatectomy had the greatest negative effect on sexual function
 - D. Urinary voiding and nocturia remained worse in the radiotherapy group

Key: A & C **NOTE: This item was double-keyed for scoring purposes upon post-exam statistical item analysis.**

Citations: N Engl J Med. Donovan et al. 2016 Oct 13. 375(15):1425-1437.
N Engl J Med. Hamdy et al. 2016 Oct 13. 375(15):1415-1424.

Rationale: The outcomes of disease control and patient reported outcomes have been reported for the ProtecT Trial. Although there was no survival advantage appreciated by either the prostatectomy or radiotherapy arms at 10 years, higher rates of disease progression were seen in the active-monitoring group, with increased development of metastasis as well. No significant differences were observed among the groups in measures of anxiety, depression, or general health-related or cancer-related quality of life. Of the three treatments, prostatectomy had the greatest negative effect on sexual function and urinary continence, and although there was some recovery, these outcomes remained worse in the prostatectomy group than in the other groups throughout the trial. Urinary voiding and nocturia were worse in the radiotherapy group at 6 months but then mostly recovered and were similar to the other groups after 12 months.

175. With regards to Meta-Analyses:
- A. all trials must be included, published or not.
 - B. raw data from each trial is not necessary for analyses.
 - C. analysis of fundamentally different interventions is allowable as long as endpoints are consistent.
 - D. combining several smaller trials is preferable to one large trial.

Key: A

Citations: Clinical Trials in Oncology, Green, Benedetti, Smith and Crowley, 2012, 212-4, CRC Press, 3rd edition.

Rationale: Though unpublished data may be very difficult to obtain, all trials should be included. Data from each trial should be retrieved and re-analysed with common endpoints, and fundamentally different interventions should not be forced into a single measure of treatment benefit.

176. Which cancer may be treated with radioactive iodine?
- A. VIPoma
 - B. Hurthle cell cancer
 - C. Medullary thyroid cancer
 - D. Anaplastic thyroid cancer

Key: B

Citations: Handbook of Evidence-Based Radiation Oncology, 3rd Ed. Hansen and Roach 2018, Springer International Publishing AG.3rd 244-245, 251-252.
NCCN Guidelines Thyroid 2018. HURT-1-9.

Rationale: Radioactive iodine has a role in the treatment of Hurthle cell cancer, which is considered a differentiated thyroid cancer. Medullary thyroid cancer is a cancer of the C-cells which secrete calcitonin and doesn't take up iodine. There is no role for radioactive iodine in the treatment of anaplastic thyroid cancer. VIPoma is not a thyroid cancer.

177. Based on the results of PORTEC-3 (LANCET Oncol 2018), what adjuvant therapy is appropriate for a 55-year-old female with pathologic Stage IB grade 3 endometrioid adenocarcinoma of the uterus with LVSI?
- A. Vaginal brachytherapy
 - B. Vaginal brachytherapy + chemotherapy
 - C. Pelvic radiation therapy
 - D. Pelvic radiation with chemotherapy

Key: C

Citations: de Boer SM, Powell ME, Mileskin L, Katsaros D, et al., Adjuvant chemoradiotherapy versus radiotherapy alone for women with high-risk endometrial cancer (PORTEC-3): final results of an international, open-label, multicentre, randomised, phase 3 trial; 2018 Lancet Oncol. 295-309.

Rationale: Based on PORTEC-3, combined adjuvant chemotherapy and radiotherapy cannot be recommended as a new standard of care for patients with stage I–II endometrial cancer because no survival differences were found and pelvic control was high with radiotherapy alone. 5-year failure-free survival for stage I–II patients was 80·8% (74·1–86·0) in the chemoradiotherapy group versus 76·6% (69·5–82·2) in the radiotherapy group (0·85, 0·54–1·33; p=0·47).

178. On the COG trial of pediatric ALL patients with isolated testicular relapse (AALL02P2), what was required for omission of testicular RT after induction chemotherapy?
- A. Resolution of testicular swelling
 - B. Resolution of testicular swelling with negative biopsy
 - C. CR on PET
 - D. CR on PET and CT

Key: A

Citations: Relander T. 2000. Gonadal and sexual function in men treated for childhood cancer. 52-63. Wiley.
Trigg ME. 2000. Early testicular biopsy in males with acute lymphoblastic leukemia: lack of impact on subsequent event-free survival. 27-33 Wiley.
Barredo JC. 2018. Isolated late testicular relapse of B-cell acute lymphoblastic leukemia treated with intensive systemic chemotherapy and response-based testicular radiation: A Children's Oncology Group study. e26928 Wiley.

Rationale: Isolated testicular relapse is often a harbinger of subsequent systemic relapse and as such salvage systemic therapy and consideration of local therapy to the testes should be considered as the testes are a sanctuary site. High dose methotrexate at salvage for patients with isolated testicular relapse has substantially improved outcomes and successfully reduced the incidence of subsequent systemic relapse. Endocrine late effects of radiotherapy are substantial and as a result, efforts by Barredo et al have been made to risk adapt radiotherapy application based on response to therapy. AALL02P2 showed that patients treated with intensified systemic therapy (including high dose methotrexate) may allow for omission of radiotherapy at the time of testicular relapse if a complete response is obtained without compromising the event free or overall survival. Patients with resolution of testicular swelling after induction chemotherapy did not need a biopsy for omission of RT. Patients with persistent testicular swelling were required to have a negative biopsy for omission of RT.

179. A 49-year-old patient has a multiply recurrent myxopapillary ependymoma of the thoracic spinal cord. Despite multiple surgeries, he has continued local progression and no other tumors in the brain or spine. What is the MOST appropriate treatment?
- A. Fractionated radiation to the involved site
 - B. Single fraction spine radiosurgery
 - C. Chemotherapy alone
 - D. Craniospinal RT with a boost

Key: A

180. What is the “power” of a test or study?
- A. The precision to which the mean of a distribution can be known
 - B. The accuracy to which the true mean of a distribution can be known
 - C. The ability to detect a true difference
 - D. The confidence level selected to compare two data sets

Key: C

Citations: Basic and Clinical Biostatistics, Dawson B and Trapp RG, 2004, pp 109 and 411. McGraw-Hill, 4th edition.

Rationale: The power of a test is the probability of detecting a difference that exists. It can be stated as the probability of rejecting the null hypothesis when it is indeed false or, equivalently, concluding that the alternative hypothesis is true when it really is true. It is intimately related to the sample size used in the study.

181. What two factors result in highest risk of a pelvic insufficiency fracture after IMRT in treating gynecologic cancers (IJROBP 2017)?
- A. Age and smoking
 - B. Age and tumor location
 - C. Tumor location and postmenopausal status
 - D. Age and postmenopausal status

Key: D

Citations: IJROBP 2017.

182. With modern systemic therapy, how does the addition of cranial RT impact outcomes in children with ALL?
- A. Decreases risk of relapse, increases risk of late effects
 - B. Decreases risk of relapse, does not impact risk of late effects
 - C. Does not impact risk of relapse, increases risk of late effects
 - D. Does not impact risk of relapse, does not impact risk of late effects

Key: C

Citations: Waber DP. 2007. Neuro-psychological outcomes from a randomized trial of triple intrathecal chemotherapy compared with 18 Gy cranial radiation as CNS treatment in acute lymphoblastic leukemia: Findings from Dana-Farber Cancer Institute ALL Consortium Protocol 95-01. 4914-4921 ASCO.

Chemaitilly W. 2015. Anterior hypopituitarism in adult survivors of childhood cancers treated with cranial radiotherapy: A report from the St Jude Lifetime Cohort study. 492-500. ASCO.

Vora A. 2016. Influence of Cranial Radiotherapy on Outcome in Children with Acute Lymphoblastic Leukemia Treated With Contemporary Therapy. 919-927. ASCO.

Rationale: Cranial radiotherapy at diagnosis is increasingly being omitted from the upfront management of even high risk pediatric ALL as results from multi-institutional studies document that cranial radiotherapy only marginally impacts leukemia control but has substantial implications for late effects in this patient population. While uncommon, some patients may not be able to receive adequate therapeutic doses of systemic therapy and so cranial radiotherapy may play a larger role in reducing the risk for subsequent relapse. In patients who are treated according to contemporary protocols, cranial radiation does not impact the risk of relapse.

183. Based on the 2015 metaanalysis by Hasan et al, in the primary treatment of early stage (I/II) squamous cell cancer of the penis, what is the 5-year LC and OS among those treated with penectomy vs. brachytherapy?
- A. Similar LC (80% vs 79%) and OS (76% vs 73%)
 - B. Improved LC (84% vs 79%) but similar OS (76% vs 73%)
 - C. Improved LC (84% vs 79%) but worse OS (70% vs 76%)
 - D. Improved LC (84% vs 79%) and OS (78% vs 71%)

Key: B

Citations: Brachytherapy. 14(4).

Rationale: Organ preservation for early stage penile SCC is often a reasonable treatment approach, with evidence suggesting a high rate of LC and OS without having to undergo penectomy. Importantly, though primary penectomy has a significantly higher chance of LC compared to brachytherapy, failures can usually be successfully salvaged with surgery, resulting in comparable rates of 5-year OS.

184. What was a CONTRAINDICATION to yttrium-90 ibritumomab tiuxetan in the randomized trial (Witzig et al. JCO 2002) for patients with relapsed or refractory low grade, follicular, or transformed B-cell non-Hodgkin lymphoma (NHL)?
- A. Tumor > 4 cm
 - B. Age < 45 years
 - C. Hemoglobin < 10 g/dL
 - D. > 25% bone marrow involvement by NHL

Key: D

Citations: JCO. Witzig et al. 2002 May 15. 20(10):2453-63.

Rationale: In the randomized trial of yttrium-90 ibritumomab tiuxetan versus rituximab for patients with relapsed or refractory low grade, follicular, or transformed B-cell NHL patients with at least 25% bone marrow involvement by lymphoma were not eligible. Hemoglobin <8 g/dL was another contraindication. Age and tumor size were not contraindications.

185. Which rectal dosimetric parameter is the MOST important in evaluating the HDR brachytherapy plan for cervical cancer?
- A. Dose to the most exposed 0.1 cm³ (D0.1cc)
 - B. Dose to the most exposed 2 cm³ (D2cc)
 - C. Average rectal dose (Dmean)
 - D. Point dose at 1 cm as measured from the vaginal packing (rectovaginal point)

Key: B

Citations: ICRU REPORT 89. Prescribing, Recording, and Reporting Brachytherapy for Cancer of the Cervix. Journal of the ICRU. 2013. 8 Oxford University Press; page 81.

Rationale: In image-based intracavitary HDR brachytherapy, rectal D2cc values have been shown to be predictive of gastrointestinal toxicity. D2cc also broadly corresponds to the ICRU rectovaginal point dose, which was used prior to the advent of cross-sectional imaging in GYN brachytherapy. While important to evaluate, the clinical significance of D0.1cc and Dmean is less clear at this point. Rectovaginal point is defined 5 mm posterior to the packing.

186. In the GRECCAR-2 trial of patients with T2-3N0-1 low lying rectal cancer, what was the rate of lymph node involvement at the time of total mesorectal excision?
- A. <10%
 - B. 11-20%
 - C. 21-30%
 - D. 31-40%

Key: A

Citations: Rullier E, et al. 2017. Organ preservation for rectal cancer (GRECCAR 2): a prospective, randomised, open-label, multicentre, phase 3 trial. *Lancet* 390(10093): 469-479.

Rationale: This French, multicenter, Phase III randomized trial included patients with T2-3N0-1 low lying rectal cancer (<8 cm from the anal verge) not involving the anal sphincter, <4 cm in diameter. There were no significant differences between local excision and TME with regard to operative death, tumor recurrence, disease-free survival, overall survival, and major morbidity. Local recurrences occurred in 5-6% of all patients with an 89% (LE) and 95% (TME) overall survival rate at 3 years. In sum, there was no superiority of local excision due to the high number of completion TMEs performed, and TMEs increased morbidity and side effects at 2 years. But the large number of nodal responses suggests that completion TME was not often necessary; only 8% of lymph nodes occurred in small, irradiated tumors. Given this small rate of lymph node positivity, the authors thought that completion surgeries could be limited to less than 10% of patients with ypT2/N1 and ypT3 tumors.

187. A 63-year-old man with a history of smokeless tobacco use presents with a 3 cm lesion on the inside of the lower lip. Biopsy shows SCC. Imaging indicates anterior mandible erosion and no lymphadenopathy or other metastasis. The patient has no significant comorbidities. What is the most appropriate treatment?
- A. Chemoradiation
 - B. Definitive radiation
 - C. Resection and neck dissection
 - D. Surgery and adjuvant radiation

Key: D

Citations: NCCN Guidelines Head and Neck. 2018. OR-3. NCCN 2.2018.
AJCC Cancer Staging Manual 2017. Ridge, et al. 79-94. Springer. 8th edition.

Rationale: The patient has T4aN0M0, stage IVA, disease of the oral cavity (buccal mucosa). The external lip is staged per head and neck cutaneous carcinomas. Assuming the patient is a good surgical candidate, resection is the primary treatment. T4 disease is an indication for adjuvant radiation. Additional indications for adjuvant radiation include perineural invasion, N2+ nodal disease, and lymphovascular invasion. Positive margins or extra nodal extension would indicate for adjuvant concurrent chemotherapy with radiation (not an option above).

188. A 3-year-old has a 3 cm orbital embryonal rhabdomyosarcoma. Staging shows no lymph node involvement or metastatic disease. What is the disease stage and group?
- A. Stage 1, Group I
 - B. Stage 3, Group I
 - C. Stage 1, Group III
 - D. Stage 2, Group II

Key: C

Citations: Rhabdomyosarcoma in Pediatric Radiation Oncology Ladra and Terezakis 2018. 23 Springer.

Rationale: Patients with non-metastatic disease at favorable sites (Orbit, Head and neck, (excluding parameningeal), GU – non-bladder/non-prostate, Biliary Tract/Liver) are stage 1. Patients who begin chemotherapy with gross disease at the primary site but no metastatic disease are Group 3.

189. For DCIS, which feature is associated with an elevated risk of in-breast recurrence?
- A. Clinical detection
 - B. Intermediate grade
 - C. Presence of ADH
 - D. Tumor-to-ink margin of 0.3 cm

Key: A

Citations: Donker M, J Clin Oncol, 2013, 31(22):4054-4059.
Wapnir IL, JNCI, 2011, 103:478-488.

Rationale: In the EORTC 10853 trial, the risk factors associated with IBTR were: age<40, clinical detection (non-mammographic), + margins, and solid type. This finding was replicated in the pooled analysis of NSABP B-17 and B-24 which found that the risk factors associated with IBTR were: age <45, clinical detection, comedonecrosis, and margin status (positive/unknown vs. negative).

190. Which protein kinase is activated by the MRN complex after the production of a radiation induced dsDNA break?
- A. Chk2
 - B. BRCA1
 - C. ATM
 - D. H2AX

Key: C

Citations: EMBO J, Uziel, Oct 2003, 22(20):5612-5621.

Rationale: ATM, which initiates mutual phosphorylation with Chk2 and a phosphorylation cascade of many downstream targets to initiate DNA repair. Can cause change in cell cycle and chromatin.

191. What is the impact of radiation therapy on chloroma?
- A. Improved local control and overall survival
 - B. Improved local control, but not overall survival
 - C. Improved overall survival, but not local control
 - D. No effect on overall survival or local control

Key: B

Citations: J Med Imaging Radiat Oncol. Hall et al. 2014 Aug. 58(4):523-7.
Int J Radiat Oncol Biol Phys. Bakst et al. 2012 Apr 1. 82(5):1816-22.

Rationale: Several retrospective series have demonstrated higher local control of chloromas treated with 20-24 Gy than is expected with chemotherapy alone although there is no effect on overall survival.

192. The addition of cisplatin-containing chemotherapy to postoperative pelvic RT for cervical cancer with a positive pelvic lymph node results in:
- A. equivalent hematologic toxicity.
 - B. lower rates of completing RT.
 - C. equivalent grade 3-4 GI toxicity.
 - D. improved OS.

Key: D

Citations: J Clin Oncol. 2000 Peters WA. 18(8):1606-13.

193. Mammalian cells are irradiated with either 4-MeV alpha particles, 250-kV X-rays, or 15-MeV neutrons. How does RBE affect cell survival?
- A. Neutron RBE is higher than alpha RBE
 - B. Neutron RBE relative to X-rays increases with dose
 - C. Neutron RBE relative to X-rays decreases with dose
 - D. Neutron RBE relative to X-rays does not change with dose

Key: C

Citations: Radiobiology for the Radiologist, Seventh ed. Hall and Giaccia, Page: 107.

Rationale: The RBE and LET of alpha particles are higher than the X rays and neutrons in this scenario, thus per dose the cell kill would be higher. In general, relative to x-ray survival, the neutron RBE decreases as the dose increases because the shoulder of the x-ray survival curve affords a high RBE at low dose/high level of survival; at higher doses both the X-ray and neutron survival curves are linear and RBE decreases relative to low doses/high survival.

194. How many days does it take for diarrhea to manifest after a whole body of 8-9 Gy γ -rays?
- A. 1-2
 - B. 4-5
 - C. 7-8
 - D. 10-11

Key: This item was 0-weighted for scoring purposes upon post-exam statistical item analysis (did not count for or against candidate in calculation of test scores)

Citations: Radiobiology for the Radiologist, Sixth Ed., Hall and Giaccia, Chapter 8 pages 338-339, Lippencott, Williams and Wilkins, 6th edition.

Rationale: Total body dose of 10 Gy γ -rays provides gastrointestinal syndrome culminating in death within 7-10 days. The symptoms are nausea, vomiting and prolonged diarrhea. If diarrhea is prolonged for several days this tends to indicate a exposure above a dose of 10 Gy. Doses in the range of 6-8 Gy produce diarrhea within 6-9 days, above 8 Gy within 4-5 days. Diarrhea is rare at doses less than 6 Gy.

195. A 70-year-old female with normal renal function and no other significant co-morbidity presents with a cT2N2M1 triple negative breast cancer with an asymptomatic bone metastasis. What is the next MOST appropriate step in treatment?
- A. Chemotherapy + RT
 - B. Endocrine therapy + RT
 - C. Chemotherapy + denosumab
 - D. Endocrine therapy + ovarian suppression

Key: C

Citations: NCCN Guidelines, Breast Cancer, April 23, 2018, BINV-19.

Rationale: Denosumab, zoledronic acid, or pamidronate should be added to endocrine or chemotherapy in the treatment of stage IV breast cancer with bone disease present, provided life expectancy is greater than 3 months and patient has normal renal function. Given that patient is asymptomatic from bone metastasis, there is no immediate need for palliative radiation.

196. Five months after surgery and chemotherapy for a right-sided stage 2 Wilms tumor, a 4-year-old relapses with two focal lesions in the left lung and one lesion in the tumor bed. All sites of recurrence are resected. What is the correct radiation dose and volume?
- A. Whole lung RT to 12 Gy and right flank RT to 21.6 Gy
 - B. Left lung RT to 12 Gy and right flank RT to 19.8 Gy
 - C. Whole lung RT to 15 Gy and right flank RT to 10.5 Gy
 - D. Whole lung RT to 15 Gy and right flank RT to 10.8 Gy followed by a tumor bed boost to 30 Gy

Key: A

Citations: Malogolowkin M. 2008. Treatment of Wilms Tumor Relapsing After Initial Treatment With Vincristine, Actinomycin D, and Doxorubicin. A Report From the National Wilms Tumor Study Group. 236-241. Wiley.
Green DM. 2007. Treatment of Wilms Tumor Relapsing After Initial Treatment With Vincristine and Actinomycin D: A Report From the National Wilms Tumor Study Group. 493-499. Wiley.
Chagtai T. 2016. Gain of 1q As a Prognostic Biomarker in Wilms Tumors (WTs) Treated with Preoperative Chemotherapy in the International Society of Paediatric Oncology (SIOP) WT 2001 Trial: A SIOP Renal Tumours Biology Consortium Study. 3195-31203 ASCO.

Rationale: Patients with gain of 1q in Wilms tumor are well known to have increased risk of relapse and are enriched in patients with blastemal predominant histology and anaplastic histology. At relapse, pathologic confirmation is required and with limited lung lesions, segmental resection of recurrent lung lesions should be pursued. Patients treated without doxorubicin should have this included as a component of relapse therapy (typically alternating cycles of VDC/CE). The dose for flank radiotherapy in the recurrent setting is recommended to be 21.6 Gy as per NWTS-5. Whole lung radiotherapy should be administered at recurrence if no prior lung radiotherapy was given. A dose of 12 Gy at 1.5 Gy/fx is recommended. Conformal boosts are not typically recommended unless gross residual disease is present following resection.

197. What is the maximum recommended dose (Gy) to large bowel per the RTOG 1112, a phase III trial, which evaluates 5 fx liver SBRT for hepatocellular carcinoma?
- A. 20
 - B. 25
 - C. 30
 - D. 35

Key: C

Citations: Dawson, L. RTOG 1112 Study Protocol.

<https://www.clinicaltrials.gov/ct2/show/NCT01730937>.

https://www.rtog.org/Portals/0/RTOG%20Broadcasts/Attachments/1112_master_w_update_5.7.13.pdf.

Rationale: For RTOG 1112, the maximum recommended dose to small bowel, large bowel, duodenum and stomach (to 0.5 cc) is 30 Gy.

198. Based upon the results of the CARMENA study (NEJM 2018), what is indicated for metastatic renal cell carcinoma?
- A. Sunitinib
 - B. Cytoreductive nephrectomy
 - C. Observation
 - D. IL-2

Key: A

Citations: Sunitinib Alone or after Nephrectomy in Metastatic Renal-Cell Carcinoma, Mejean, A2018, N Engl J Med. 2018, Jun 3. doi: 10.1056/NEJMoa1803675. [Epub ahead of print]

Rationale: The results in the sunitinib-alone group were noninferior to those in the nephrectomy-sunitinib group with regard to overall survival (stratified hazard ratio for death, 0.89; 95% confidence interval, 0.71 to 1.10; upper boundary of the 95% confidence interval for noninferiority, ≤ 1.20). The median overall survival was 18.4 months in the sunitinib-alone group and 13.9 months in the nephrectomy-sunitinib group. No significant differences in response rate or progression-free survival were observed.

199. An SRS plan for 20 Gy to a single brain metastasis from melanoma would deliver a dose to the optic chiasm of 16 Gy due to the proximity of a patient's tumor to the optic pathways. What is
- A. Treat the tumor to 20 Gy and limit the chiasm dose to <16 Gy
 - B. Treat the tumor to 10 Gy and limit the chiasm dose to <8 Gy
 - C. Cancel SRS and treat with WBRT
 - D. Treat with fractionated SRS

Key: D

200. Two recently published randomized trials (Gomez et al. 2016, Iyengar et al. 2018) for patients with oligometastatic NSCLC, addition of local consolidative therapy to maintenance chemotherapy results in:
- A. no change in PFS or OS.
 - B. increased Grade 4+ toxicity.
 - C. reduced compliance to chemotherapy.
 - D. improved PFS.

Key: D

Citations: Lancet Oncolog. Gomez DR et al. Oct 24, 2016 1672-82.
JAMA Oncology Iyengar P et al. 2018 1-8.

Rationale: Gomez et al. 2016 and Iyengar et al. 2018 are two Phase II RCTs examining in NSCLC patients with oligometastatic disease (defined as 1-3 sites vs. primary with up to 5 sites, respectively) whether the addition of local consolidative therapy (surgery and/or RT vs. SAbR/SBRT alone, respectively) compared to maintenance chemotherapy alone affected PFS, which was nearly tripled in both studies (Gomez et al. median PFS 11.9 months vs. 3.9 months, $p=0.0054$; Iyengar et al. median PFS 9.7 months vs. 3.5 months, $P=0.01$). Both trials were stopped at interim analysis after finding significant improvement in PFS. Both studies were not powered to look at OS, and neither study demonstrated worse toxicity with consolidative therapy. Ongoing NRG LU-002 study is a randomized phase II/III study testing the role of consolidative SBRT.

201. ECOG 1308 was a phase II trial that examined radiation dose de-escalation in patients with oropharyngeal HPV-associated SCC after induction chemotherapy. For patients who achieved a clinical complete response, what dose did the primary site and initially involved nodes receive?
- A. 50.4 Gy
 - B. 54 Gy
 - C. 60 Gy
 - D. 63 Gy

Key: B

Citations: Marur, et al., E1308: Phase II Trial of Induction Chemotherapy Followed by Reduced-Dose Radiation and Weekly Cetuximab in Patients With HPV-Associated Resectable Squamous Cell Carcinoma of the Oropharynx-ECOG-ACRIN Cancer Research Group. 2017. 490–497. JCO 35(5).

Rationale: Patients with HPV16 and/or p16-positive, stage III-IV oropharyngeal SCC received three cycles of inductive chemotherapy with cisplatin, paclitaxel, and cetuximab. Patients with primary-site cCR received 54 Gy IMRT with weekly cetuximab. Those with less than cCR received 69.3 Gy and cetuximab to those regions. The primary end point was 2-year progression-free survival. 70% achieved a primary-site cCR and 51 patients continued to cetuximab with 54 Gy IMRT. After median follow-up of 35.4 months, 2-year PFS and OS rates were 80% and 94%. PFS was low in the overall study but favourable patients (non-T4, non-N2c, ≤ 10 pack-year smokers) showed better outcomes. Radiation dose reduction resulted in significantly improved swallowing and nutritional status.

202. Which statements BEST describes the proper RT dose constraint when evaluating a treatment plan for a thoracic tumor?
- A. Spinal Cord Dmax 24 Gy for a SABR/SBRT plan of 54 Gy in 3 fractions
 - B. Spinal Cord Dmax 41 Gy for a LS-SCLC chemoradiation plan (45 Gy in 1.5 Gy BID)
 - C. Mean Lung Dose 18 Gy for Post-operative RT after extrapleural pneumonectomy for mesothelioma
 - D. Brachial plexus Dmax of 71 Gy for a superior sulcus tumor, being treated with conventionally fractionated chemoradiation therapy

Key: B

Citations: CALGB30610 dose constraints in the protocol. J Bogart.

Rationale: A is incorrect since the Dmax to the cord for 54 Gy in 3 fractions is 6 Gy per fraction, or 18 Gy; B is correct because the current RTOG trials allow 41 Gy Dmax for the Turrisi regimen, which is higher than the original Turrisi constraint of 36 Gy; C is incorrect because mean lung dose of the remaining lung should be < 8.5 Gy; D is incorrect because brachial plexus should only receive 66 Gy in 2 Gy per fraction.

203. In RTOG 0529, a Phase II study of dose painted IMRT for anal cancer, what volume of small bowel receiving 40 Gy correlated with an increased risk of acute grade >2 GI adverse events?
- A. 30 cc
 - B. 50 cc
 - C. 70 cc
 - D. 90 cc

Key: This item was 0-weighted for scoring purposes upon post-exam statistical item analysis (did not count for or against candidate in calculation of test scores)

Citations: Olsen JR. 2017. Predictors of Radiation Therapy-Related Gastrointestinal Toxicity From Anal Cancer Dose-Painted Intensity Modulated Radiation Therapy: Secondary Analysis of NRG Oncology RTOG 0529. *IJROBP* 98(2): 400-408.

Rationale: Among 52 evaluable patients, grade ≥ 2 acute, grade ≥ 2 late, and grade ≥ 3 acute GI AEs were observed in 35, 17, and 10 patients, respectively. Trends ($P < .05$) toward statistically significant associations were observed between grade ≥ 2 acute GI AEs and small bowel dose (V20-V40), grade ≥ 2 late GI AEs and anterior pelvic contents (APC) dose (V60), grade ≥ 3 acute GI AEs and APC dose (V5-V25), increasing age, tumor size >4 cm, and worse Zubrod performance status. Small bowel volumes of 186.0 cc, 155.0 cc, 41.0 cc, and 30.4 cc receiving doses greater than 25, 30, 35, and 40 Gy, respectively, correlated with increased risk of acute grade ≥ 2 GI AEs.

204. Which patient with a low grade glioma would benefit from radiation followed by chemotherapy instead of radiation alone?
- A. 50-year-old with subtotal resection
 - B. 1-year-old with subtotal resection
 - C. 23-year-old with gross total resection
 - D. 37-year-old with gross total resection

Key: A

Citations: Radiation plus Procarbazine, CCNU, and Vincristine in Low-Grade Glioma. Buckner JC, Shaw EG et al. 2016 Apr 7. 374(14):1344-55. *N Engl J Med*.

Rationale: RTOG 9802 randomized high risk low grade glioma patients, defined as either >40 years only or subtotal resection, to either radiation versus radiation followed by PCV. The updated analysis found both a progression free survival benefit and overall survival benefit.

205. In the 2016 Polish Colorectal Study Group for fixed cT3 or T4 rectal cancer, compared to long course oxaliplatin-based CRT, the short course RT (5 Gy x 5 Fx) followed by consolidation chemotherapy:
- A. increased R1 resection rates.
 - B. decreased acute toxicity.
 - C. decreased disease-free survival.
 - D. increased pCR rates.

Key: B

Citations: Long-course oxaliplatin-based preoperative chemoradiation versus 5 × 5 Gy and consolidation chemotherapy for cT4 or fixed cT3 rectal cancer: results of a randomized phase III study, Bujko K. et al., 2016 May 27(5):834-42.

Rationale: Patients with fixed cT3 or cT4 cancer were randomized either to 5 × 5 Gy and three cycles of FOLFOX4 (group A) or to 50.4 Gy in 28 fractions combined with two 5-day cycles of bolus 5-Fu 325 mg/m²/day and leucovorin 20 mg/m²/day during the first and fifth week of irradiation along with five infusions of oxaliplatin 50 mg/m² once weekly (group B).

Preoperative treatment acute toxicity was lower in group A than group B, P = 0.006; any toxicity being, respectively, 75% versus 83%, grade III-IV 23% versus 21% and toxic deaths 1% versus 3%. R0 resection rates (primary end point) and pathological complete response rates in groups A and B were, respectively, 77% versus 71%, P = 0.07, and 16% versus 12%, P = 0.17. The median follow-up was 35 months. At 3 years, the rates of overall survival and disease-free survival in groups A and B were, respectively, 73% versus 65%, P = 0.046, and 53% versus 52%, P = 0.85, together with the cumulative incidence of local failure and distant metastases being, respectively, 22% versus 21%, P = 0.82, and 30% versus 27%, P = 0.26. Postoperative and late complications rates in group A and group B were, respectively, 29% versus 25%, P = 0.18, and 20% versus 22%, P = 0.54.

206. For IGRT, which technique delivers the highest imaging radiation dose to the patient?
- A. MV portal imaging
 - B. kV cone-beam CT
 - C. kV planar imaging
 - D. Surface imaging

Key: B

Citations: Practical Radiation Oncology, Physics, Sonja Dieterich, 2016, 98, Elsevier, 1st edition.

Rationale: The typical doses are 10 - 30 mGy per scan for kV cone-beam CT, 0.1 - 3 mGy per MU for MV portal imaging, <1 mGy per image for kV planar imaging, and no dose for surface imaging (no ionizing radiation used).

207. What is the FIGO stage for a cervical carcinoma with involvement of the distal third of the vagina and hydronephrosis?
- A. IIA2
 - B. IIB
 - C. IIIA
 - D. IIIB

Key: D

Citations: Springer, AJCC Cancer staging Manual, 7th edition, 2010, 395-402.

Rationale: By FIGO staging hydronephrosis upstages to FIGO IIIB.

208. What were the doses for WBI and APBI used on the NSABP B-39/RTOG 0413 clinical trial for women with stage 0, I, II breast cancers?
- A. WBI 42 Gy in 16 fx; APBI 34 Gy in 10 fx bid brachy; APBI 38.5 Gy in 10 fx bid 3D CRT
 - B. WBI 42 Gy in 16 fx; APBI 38.5 Gy in 10 fx bid brachy; APBI 34 Gy in 10 fx bid 3D CRT
 - C. WBI 50 Gy in 25 fx; APBI 34 Gy in 10 fx bid brachy; APBI 38.5 Gy in 10 fx bid 3D CRT
 - D. WBI 50 Gy in 25 Fx; APBI 38.5 Gy in 10 fx bid brachy; APBI 34 Gy in 10 fx bid 3D CRT

Key: C

Citations: Julian TB et al., IJROBP, 2001, 81(2), S7 (abstract).

NSABP B-39/RTOG 0413 protocol.

Rationale: On NSABP B-39/RTOG 0413 women with stage 0, I, or II breast cancers with tumor size less than 3 cm and no more than 3 LNs positive were stratified by disease stage, menopausal status, hormone receptor status, and intention to receive chemotherapy. They were randomized to either WBI as 50 Gy (2 Gy/fx) or 50.4 Gy (1.8 Gy/fx) with optional boost versus 34 Gy (3.4 Gy/fx bid) with multicatheter or intracavitary brachytherapy or 38.5 Gy (3.85 Gy/fx bid) with 3D conformal EBRT.

209. Which radiation-induced aberration is often nonlethal to cells?

- A. Dicentric
- B. Ring
- C. Interstitial deletion
- D. Anaphase bridge

Key: C

Citations: Radiation Biology for the Radiologist. Eric Hall and Amato Giaccia 2012. 27 Lippincott Williams Wilkins, 7th edition.

Rationale: Symmetric translocations and small interstitial deletions are nonlethal chromosomal aberrations. The others mentioned are gross chromosomal distortions that are often lethal to the cell.

210. What was shown in the MegaMouse project?

- A. Temporary sterility in males with doses >6 Gy
- B. Males were less radiosensitive than females
- C. Increased time between exposure and conception increased genetic effects
- D. Mutations increased linearly with dose and dose rate

Key: D

Citations: Mutation frequencies in male mice and the estimation of genetic hazards of radiation in men. Russell WL and Kelley EM. PNAS. 1982; 79(2): 542-544.

Specific-locus mutation frequencies in mouse stem-cell spermatogonia at very low radiation dose rates. Russell WL and Kelley EM. PNAS 1982. 79(2) 539-41.

Rationale: Mutations increase linearly with dose and dose rate but with a different slope to the dose response curve. Males were more radiosensitive than females. Temporary sterility in males was seen with doses significantly less than 1 Gy. The longer the period between radiation exposure and conception, the less the genetic effects on the offspring.

211. During the treatment planning process, how are CT image pixel values converted into relative electron density?
- A. Calibrated using a known electron density phantom
 - B. Measured using a diode array
 - C. Using gold data from the CT manufacturer
 - D. Using water tank scanning data

Key: A

Citations: The Physics of Radiation Therapy, Faiz Khan, 2014, 413, Lippincott, Williams, Wilkins, 5th edition.

Rationale: CT pixel values need to be converted to electron density in order to calculate dose. A phantom with known electron density values will have corresponding pixel values when it is imaged with the CT scanner. A calibration curve is generated using these values, which then is used to convert pixel values in patient images.

212. Which radiotracer indicates areas of metabolism in a PET scan?
- A. Diethylenetriaminepentaacetic acid (DTPA)
 - B. Fluorodeoxyglucose (FDG)
 - C. Macroaggregated albumin (MAA)
 - D. Methylene diphosphonate (MDP)

Key: B

Citations: The Essential Physics of Medical Imaging, Bushberg, Seibert, Leidholdt Jr., Boone, 2012, 614-615, Lippincott Williams Wilkins, 3rd edition.

Rationale: Fluorodeoxyglucose (FDG) can be created with the positron emitter F-18 and accumulates in areas of glucose metabolism. The remainder of the radiotracers listed are based the gamma emitter Tc-99m.

213. Which treatment is not effective for radiation necrosis?

- A. Dexamethasone
- B. Bevacizumab
- C. Intrathecal chemotherapy
- D. Resection

Key: C

214. What is the overall response rate associated with total skin electron beam therapy (TSEBT) for mycosis fungoides prescribed to 12 Gy delivered using 1 Gy per fraction over 3 weeks?

- A. 10%
- B. 30%
- C. 60%
- D. 90%

Key: D

Citations: J Am Acad Dermatol. Hoppe et al.2015 Feb 72(2):286-92.

Rationale: In a pooled analysis from three phase 2 clinical trials, TSEBT delivered to 12 Gy instead of standard 36 Gy resulted in an overall response rate of 88% including 9 patients with a complete response. While response may be less durable with low dose TSEBT, patients may still achieve significant clinical benefit and with less toxicity.

215. All of the following are strategies for motion management in treatment of liver tumors EXCEPT:

- A. active breath hold.
- B. free breathing.
- C. respiratory gating.
- D. forced shallow-breathing methods.

Key: B

Citations: AAPM 2006. The Management of Respiratory Motion in Radiation Oncology. AAPM Report No. 91.

Rationale: Only free breathing does not involve a technique to either reduce excursion by the tumor due to breathing motion (a,d) or reducing margin by tracking the tumor (or a surrogate for the tumor).

216. Which of the following is influenced by the prevalence of disease in the population that is being tested?
- A. Sensitivity
 - B. Specificity
 - C. True negative test
 - D. Positive predictive values

Key: D

Citations: Sensitivity, Specificity, Positive Predictive Value, and Negative Predictive Value;
<https://onlinecourses.science.psu.edu/stat507/node/71>.

Rationale: If we test in a high prevalence setting, it is more likely that subjects who test positive truly have disease than if the test is performed in a population with low prevalence. It is illustrated in below two examples, the total population is 100 subjects and there are same sensitivity and specificity but different prevalence of disease.

Example 1: Prevalence of disease= $(10+5)/100=15\%$.

Test Results	Disease Status	
	Present	Absent
Positive	10	40
Negative	5	45

Sensitivity= $10/(10+5)=66.7\%$;
 Specificity= $45/(40+45)=52.9\%$;
 Positive predictive values= $10/(10+40)=20\%$;
 Negative predictive values= $45/(5+45)=90\%$.

Example 2: Prevalence of disease= $(20+10)/100=30\%$.

Test Results	Disease Status	
	Present	Absent
Positive	20	33
Negative	10	37

Sensitivity= $20/(20+10)=66.7\%$;
 Specificity= $37/(33+37)=52.9\%$;
 Positive predictive values= $20/(20+33)=38\%$;
 Negative predictive values= $37/(10+37)=79\%$.

Using the same test in a population with higher prevalence increases positive predictive value. Conversely, increased prevalence results in decreased negative predictive value.

217. What is the appropriate range of fractionated EBRT doses for a recurrent grade I meningioma?
- A. 12 - 14 Gy
 - B. 30 - 36 Gy
 - C. 50.4 - 54 Gy
 - D. 60 - 66 Gy

Key: C

Citations: Meningiomas: knowledge base, treatment outcomes, and uncertainties. A RANO review. Rogers L et al. 2015 Jan. 122(1):4-23. J Neurosurg.

Rationale: Fractionated radiation doses range from 50 to 54Gy in 1.8's to 2's. RTOG 0539 used dose of 54Gy for intermediate risk meningiomas.

218. What is the principle mechanism of action of gemcitabine?
- A. Induction of DNA dsbs
 - B. Induction of interstrand crosslinks
 - C. Inhibition of DNA synthesis and repair
 - D. Inhibition of mRNA polyadenylation

Key: C

Citations: Biologic basis for combining drugs with radiation. Wilson GD, Bentzen SM, Harari PM. Semin Radiat Oncol. 2006 Jan; 16(1):2-9.

Rationale: Gemcitabine is a pyrimidine analog that also has a wide range of activity against solid tumors. The drug's mechanism of action is through depletion of the deoxynucleoside triphosphate pool and incorporation into DNA with subsequent inhibition of DNA synthesis and repair. Gemcitabine has been found to be a potent radiosensitizer in a variety of human cell lines including colon, pancreatic, breast, and non-small-cell lung cancer.

219. Which are the expected optic neuropathy rates following conventionally fractionated (i.e. ≤ 2 Gy per fraction) irradiation of the optic nerve and chiasm?
- A. <3% at 60 Gy and 5% at 65 Gy
 - B. <3% at 55 Gy and 5% at 60 Gy
 - C. <3% at 50 Gy and 10% at 55 Gy
 - D. <3% at 45 Gy and 10% at 50 Gy

Key: B

Citations: Use of normal tissue complication probability models in the clinic. Marks, et al. 2010. IJROBP, S10–S19; 76(3 Suppl).

Rationale: The QUANTEC dose-volume limit summary lists optic neuropathy rates of <3% for 55 Gy, 3-7% for 55-60 Gy, and 7-20% for >60 Gy.

220. What is the MOST appropriate dose of radiation for a patient with high risk neuroblastoma and no gross disease after chemotherapy?
- A. No radiation
 - B. 10.6 Gy
 - C. 21.6 Gy
 - D. 36 Gy

Key: C

Citations: Neuroblastoma in Pediatric Radiation Oncology Panoff, Lucas, Pater, and Gajjar 2018 98 Springer.

Rationale: Patients who have no gross residual disease should receive 21.6 Gy in 1.8 Gy fractions.

221. Which renal cell subtypes is MOST vulnerable to cisplatin nephrotoxicity?
- A. Glomerular podocytes
 - B. Proximal tubular cells
 - C. Mesangial cells
 - D. Corpuscles

Key: B

Citations: Radiobiology for the Radiologist, Sixth Ed., Hall and Giaccia, Chapter 19, 338-364.

G. Ciarimboli, T. Ludwig, D. Lang, et al., Cisplatin nephrotoxicity is critically mediated via human organ cation transporter 2, *Am. J. Pathol.* 167 (2005) 1477e1484.

Rationale: The kidney is a radiosensitive organ and a critical late responding normal tissues. With little re-treatment tolerance. Radiation damage develops slowly with time after treatment and progresses. The functional subunits are arranged in parallel and the critical podocytes and tubular cells show little mitotic activity; and hence the organ is among the most radiosensitive. Although cisplatin is currently the drug of choice in many platinum-based therapy regimens, nephrotoxicity has been reported to be a major side effect of high-dose cisplatin therapy that occurs in 20-30% of patients receiving high-dose cisplatin. Cisplatin-induced nephrotoxicity was reported in the initial clinical trials of cisplatin chemotherapy, showing acute renal failure in 14-100% of patients in cumulative dose. Quiescent proximal tubular cells are most vulnerable to cisplatin nephrotoxicity.

222. Iacobuzio-Donahue et al. published a series of rapid autopsies of 76 pancreatic cancer patients in *JCO* in 2009. What was the breakdown of the two patterns of failure?
- A. 95% widespread metastatic / 5% locally destructive
 - B. 70% widespread metastatic / 30% locally destructive
 - C. 51% widespread metastatic / 49% locally destructive
 - D. 30% widespread metastatic / 70% locally destructive

Key: B

Citations: *J Clin Oncol* 2009; 27:1806-1813.

Rationale: This series, known as the “Hopkins Rapid Autopsy Series” determined that while the majority of pancreatic cancer patients died of metastatic disease (70%), the cause of death was local.

223. Two groups of prostate cancer patients previously treated with radiation to the same prescription dose (one group with rectal bleeding, one group without rectal bleeding) are evaluated for treatment technique to determine if IMRT can reduce rectal toxicity compared to 3D conformal therapy. What type of study is this?
- A. Cohort study
 - B. Case-control study
 - C. Randomized controlled trial
 - D. Crossover study

Key: B

Citations: Basic and Clinical Biostatistics, Dawson B and Trapp RG, 2004, pp 333 and 404, McGraw-Hill, 4th edition.

Rationale: A case-control study is an observational study that begins with patient cases who have the outcome (rectal toxicity in this case) or disease being investigated and control subjects who do not have the outcome or disease. It then looks backward to identify possible precursors or risk factors.

224. Which organ is likely to be spared with IMRT vs 3D-conformal RT in a postoperative RT plan for a node positive adenocarcinoma of the gastric body?
- A. Liver parenchyma
 - B. Small bowel
 - C. Kidneys
 - D. Spinal cord

Key: C

Citations: IMRT for postoperative treatment of gastric cancer: covering large target volumes in the upper abdomen: a comparison of a step-and-shoot and an arc therapy approach, Wieland P., 2004, Jul 1559(4):1236-44.

Rationale: In this case the left kidney would be best spared with IMRT. In dosimetric studies, the median kidney dose generated from the IMRT plans is reduced individually by >50% for the kidney with the highest exposure (usually the left kidney) from 20 to 30 Gy with conventional 3D planning down to values between 8 and 10 Gy for IMRT. On average, median dose to the right kidney is the same for the conventional box technique and IMRT (between 8 and 10 Gy) but lower for the AP-PA technique. In 3 patients, kidney dose might have been ablative for both kidneys with both the AP-PA technique and the box technique, whereas it was acceptable with IMRT. Median dose to the liver was subcritical with all modalities but lowest with AP-PA fields. Differences between step-and-shoot IMRT and tomotherapy plans are small when compared to the differences between IMRT plans and conventional conformal 3D plans. For some patients, however, their body and target diameters obviate treatment with tomotherapy.

225. Which parameter is NOT a measure of central tendency?

- A. Mean
- B. Mode
- C. Median
- D. Range

Key: D

Citations: Basic & Clinical Biostatistics, Saunders & Trapp, 1999, 42-44, Appleton and Lange, 2nd edition.

Rationale: Measures of central tendency are statistics that describe the location of a distribution of numerical and ordinal measurements. Median, mode and mean accomplish this. However, range is a measure of dispersion.

226. A patient with vaginal cancer has been treated with surgery and adjuvant brachytherapy. She presents in follow up with a symptomatic vaginal perforation but does not require surgical correction. What is the assigned CTCAE grade (Common Terminology Criteria of Adverse Events)?

- A. 1
- B. 2
- C. 3
- D. 4

Key: B

227. Primary Mediastinal Large B Cell Lymphoma (PMBL):

- A. only presents in the mediastinum.
- B. has histology of DLBCL.
- C. can only be treated with R-EPOCH.
- D. should always be receive RT after R-EPOCH.

Key: B

Citations: NCCN Guidelines Version 4. 2018 Zelenetz et al. March 27, 2017; BCEL-B 1 of 3; NCCN.

Rationale: PMBL is a distinct clinical entity that can present with primary disease in mediastinum with or without other sites, and can overlap with grey zone lymphomas. PMBL can be treated with R-EPOCH x 6 cycles. RT is not always indicated after R-EPOCH, but can be considered for persistent focal disease. Other treatment options for PMBL include RCHOP x 6+RT, as well as RCHOPx 4 followed by ICE x 3 +/- RT. Clinically, physicians should pay attention and distinguish PMBL from conventional PMBL. Clinical, pathological correlation is required to establish this diagnosis.

228. In the EORTC H10 study, patients that received an additional 1 cycle of ABVD+ INRT after the initial 2 cycles of ABVD and were noted to be complete response on interim PET/CT had:

- A. inferior PFS compared with ABVD alone.
- B. superior PFS compared with ABVD alone.
- C. inferior OS compared with ABVD alone.
- D. superior OS compared with ABVD alone.

Key: B

Citations: Early Positron Emission Tomography Response-Adapted Treatment in Stage I and II Hodgkin Lymphoma: Final Results of the Randomized EORTC/LYSA/FIL H10 Trial, Andre MP, 6/1/2017, 1786-1794, Journal Clinical Oncology.

Rationale: Patients had improved PFS but similar OS if they got 1 more cycles of ABVD and INRT.

229. What are the appropriate regional nodal treatment volumes for a pT2N1 breast cancer following modified radical mastectomy?
- A. Supraclavicular, infraclavicular, and dissected axilla
 - B. Supraclavicular, axillary apical, and ipsilateral IMNs
 - C. Supraclavicular and bilateral IMNs
 - D. Infraclavicular and ipsilateral IMNs

Key: B

Citations: Recht et al, JCO, 2016: 34(36), 4431-4442.

Rationale: According to a focused guideline update on PMRT from ASCO/ASTRO/SSO: RNI should include the IMNs and supraclavicular-axillary apical nodes. Axillary LND is included in MRM. The dissected axilla should not be included for N1 disease.

230. In patients who receive total body irradiation, what is the rationale for treatment with reduced dose rate?
- A. Reduced risk of pneumonitis
 - B. Reduced risk of fatigue
 - C. Reduced risk of secondary cancers
 - D. Reduced risk of myelopathy

Key: A

Citations: Int J Radiat Oncol Biol Phys. Abugideiri et al. 2016 Feb 1. 94(2):349-59.
Br J Cancer. Carruthers et al. 2004 Jun 1. 90(11):2080-4.

Rationale: A reduced dose rate of (i.e. 0.05-0.1 Gy/min) has been shown in multiple preclinical and clinical studies to decrease the incidence of interstitial pneumonitis from total body irradiation.

231. Which of the following is a NCCN guideline approved regimen for concurrent chemotherapy during definitive NSCLC chemoradiation?

- A. Cisplatin 50 mg/m² days 1, 8 and etoposide 50 mg/m² days 1-5 weeks 1 and 5
- B. Carboplatin AUC 6 and Paclitaxel 200 mg/m² weekly
- C. Cisplatin 75 mg/m² and Pemetrexed 500 mg/m² weekly
- D. Carboplatin AUC 5 day 1 and Gemcitabine 1000 mg/m² days 1, 8, 21 every 21 days

Key: A

Citations: NCCN guidelines V6.2018 NSLC-EJ.
Clin Oncol Albain KS. 2002; 3454-60.

Rationale: Carboplatin and paclitaxel weekly must be dose reduced (AUC 2 and 50 mg/m²). Cisplatin and pemetrexed are given every 3 weeks. Gemcitabine should not be used during chest RT as it is a potent enhancer of esophageal toxicity.

232. A patient with clinical T2N0M0 SCC of the supraglottic larynx involving the left aryepiglottic fold should receive treatment to the:

- A. primary site only.
- B. primary site and ipsilateral neck.
- C. primary site and bilateral neck.
- D. primary site, bilateral neck, and upper mediastinum.

Key: C

Citations: Levendag and Vikram. The problem of neck relapse in early stage supraglottic cancer--results of different treatment modalities for the clinically negative neck. 1987 Nov. 1621-4. IJROBP. 13(11).
Supraglottic carcinoma: patterns of recurrence. Lutz, et al. 1990 Jan. 12-7. Ann Otol Rhinol Laryngol. 99(1).

Rationale: Supraglottic tumors are treated with bilateral neck irradiation due to the high rate of neck failure observed in the untreated contralateral neck among patients treated surgically or with radiation.

233. Which is an acceptable dose prescription for favorable intermediate risk prostate cancer?
- A. Low dose rate brachytherapy alone 125I – 110 Gy
 - B. Low dose rate brachytherapy alone 103Pd – 125 Gy
 - C. Low dose rate brachytherapy alone 131CS – 85 Gy
 - D. High dose rate brachytherapy alone 192Ir – 16 Gy (8 Gy X 2 implants)

Key: B

Citations: NCCN Prostate Guidelines Version 3 2018.

Rationale: The NCCN guidelines recommends low dose rate brachytherapy alone. Iodine 125 is 145 Gy, Palladium 103 is 125 Gy, Cesium 131 is 115 Gy, or high dose rate brachytherapy alone Iridium 192 is 27 Gy in two implants.

234. What is the stage of a vulvar cancer that extends to the distal one-third of the urethra with 3 lymph nodes containing metastases each less than 5 mm?
- A. II
 - B. IIIA
 - C. IIIB
 - D. IIIC

Key: C

235. According to ICRU Report #39, the dose to the skin should be specified at a depth of:
- A. 0.00 mm.
 - B. 0.07 mm.
 - C. 1.00 mm.
 - D. dmax.

Key: B

Citations: The Physics and Technology of Radiation Therapy, McDermott Orton, 2010, Medical Physics Publishing, 1st edition.

ICRU Report #39, Determination of Dose Equivalents Resulting from External Radiation Sources, ICRU, 1985, 2, ICRU.

Rationale: The base of the epidermis is at a depth of about 100 micron. This corresponds roughly to a depth of 0.07 mm.

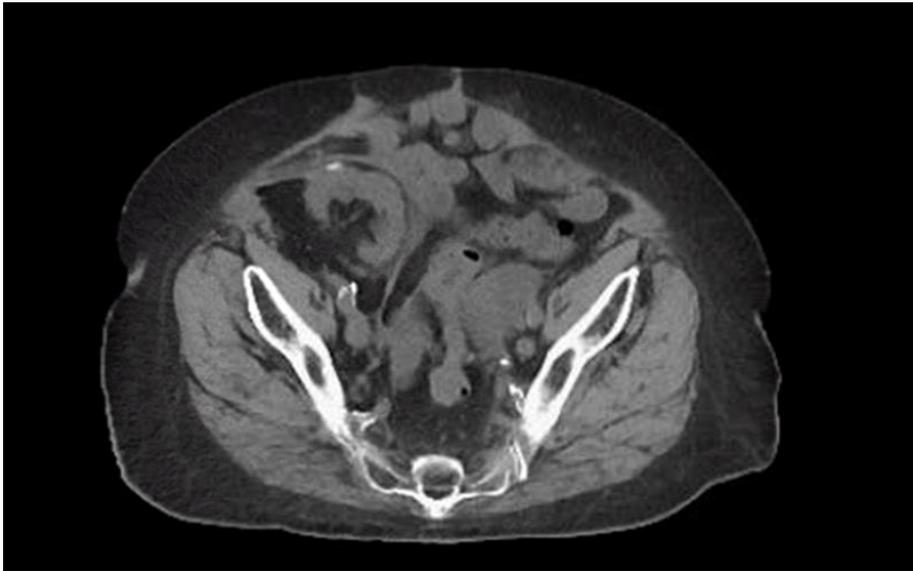
236. In a randomized trial of limited stage SCLC (Turrissi et al) comparing 45 Gy delivered BID versus 45 Gy once daily, what was shown with BID?
- A. A 5 times increase in grade 3 esophagitis
 - B. Improved local control at the primary site
 - C. Significantly improved 2-year OS
 - D. Similar 5-year OS

Key: B

Citations: New Engl J Med Turrissi AT 3rd 1999 Jan 28; 265.

Rationale: Turrissi et al showed BID radiation reduced the rate of local failure from 52% to 36% ($p=0.06$). BID radiation resulted in an increase of grade 3 esophagitis by 2-3 fold (11% to 27%). The 2 year survival outcomes (47% versus 41%) were not significantly different, but the survival curves separated late (consistent with improved local control) resulting in a 26% vs 16% 5 year overall survival benefit ($p=0.04$).

237. A patient that has had a prior kidney transplant now requires adjuvant pelvic radiation for a Stage II G3 endometrioid endometrial cancer. What is the MOST critical organ at risk on the acquired CT simulation image?



- A. Bone Marrow
- B. Transplanted kidney
- C. Bladder
- D. Small Bowel

Key: B

Rationale: In the provided image, a transplanted kidney is present in the right lower quadrant (circle). The transplanted kidney is the most critical OAR and dose should be minimized as much as possible. Other OARs listed in the stem should also be limited to their respective tolerances.

238. What category of Wilms tumor patients had the WORST prognosis on the National Wilms Tumor Study V?
- A. Stage IV, favorable histology, with loss of heterozygosity of 1p and 16q
 - B. Stage V, favorable histology, any loss of heterozygosity
 - C. Stage II diffuse anaplasia histology
 - D. Stage IV diffuse anaplasia histology

Key: D

Citations: Dome JS, et al., Childrens Oncology Groups, 2013, blueprint for research: renal tumors. *Pediatr Blood Cancer*, 2013, Jun; 60(6):994-1000. doi: 10.1002/pbc.24419. Epub 2012 Dec 19.

Rationale: Although loss of heterozygosity of 1p and 16q is a negative prognostic factor, diffuse anaplasia histology is a more important negative prognostic factor. In NWTs-V patients with Stage IV diffuse anaplasia histology had a 4 year overall survival of 33%, with all other categories of patients in this question having 4 year overall survivals of greater than 50% (including patients with stage V, favorable histology Wilms tumor with any loss of heterozygosity having a 4 year overall survival of 80%).

239. What is an advantage of kV cone-beam CT (CBCT) over MV portal imaging for IGRT?
- A. Reduced acquisition time
 - B. Better soft tissue visualization
 - C. Better high contrast spatial resolution
 - D. Reduced image artifacts

Key: B

Citations: *Practical Radiation Oncology Physics*, Sonja Dieterich, 2016, 245, Elsevier, 1st edition.

Rationale: Imaging with a kV beam results in enhanced soft tissue contrast compared with an MV beam due to higher contribution of photoelectric effect.

240. In a patient with oral SCC, what is the pathological N stage for a single positive lymph node, 1 cm, with extracapsular extension?
- A. pN1b
 - B. pN2a
 - C. pN2c
 - D. pN3

Key: B

Citations: AJCC Cancer Staging Manual. Ridge et al. 2017. 79-94, Springer. 8th edition.

Rationale: Pathologic N staging for head and neck cancers is new in AJCC VIII. Extranodal extension indicates N3 disease for HPV negative SCC, except for single nodal metastasis less than 3 cm in size where it is N2a.

241. Per ASTRO guidelines, which pathologic features in a patient with Stage I endometrioid endometrial cancer warrant postoperative vaginal cuff radiation alone?
- A. Grade 1 and <50% invasion
 - B. Grade 2 and $\geq 50\%$ invasion
 - C. Grade 3 and $\geq 50\%$ invasion
 - D. Grade 3 and invasion involving serosa

Key: B

Citations: The Role of Postoperative Radiation Therapy for Endometrial Cancer: An ASTRO Evidence-Based Guideline, Klopp, 2014, 1-20, Practical Radiation Oncology.

Rationale: Vaginal cuff brachytherapy is as effective as pelvic RT in preventing vaginal recurrence for patients with grade 1 or 2 cancers with $\geq 50\%$ myometrial invasion or grade 3 with < 50% myometrial invasion. In general grade 1 cancers with <50% do not require adjuvant radiation.

242. According to recent ACR breast cancer screening recommendations, what would be appropriate annual screening for women with calculated lifetime breast cancer risk of 20% or more?
- A. MRI with IV contrast starting at age 20
 - B. Digital breast tomosynthesis starting at age 20
 - C. Ultrasound of the breast starting at age 25
 - D. Digital mammography starting at age 30

Key: D

Citations: Monticciolo et al, American College of Radiology, J Am Coll Radiol, 2018:15, p. 408-414.

Rationale: The updated ACR breast cancer screening recommendations for women at higher-than-average risk state the following: “For women with genetics-based increased risk (and their untested first-degree relatives) or with a calculated lifetime risk of 20% or more, DM, with or without DBT, should be performed annually beginning at age 30. For women with histories of chest radiation therapy before the age of 30, DM, with or without DBT, should be performed annually beginning at age 25 or 8 years after radiation therapy, whichever is later. For women with genetics-based increased risk (and their untested first-degree relatives), histories of chest radiation (cumulative dose of 10 Gy before age 30), or a calculated lifetime risk of 20% or more, breast MRI should be performed annually beginning at age 25 to 30. For women with personal histories of breast cancer and dense breast tissue, or those diagnosed before age 50, annual surveillance with breast MRI is recommended. For women with personal histories not included in the above, or with ADH, atypical lobular hyperplasia, or LCIS, MRI should be considered, especially if other risk factors are present. All women, especially black women and those of Ashkenazi Jewish descent, should be evaluated for breast cancer risk no later than age 30, so that those at higher risk can be identified and can benefit from supplemental screening.”

243. Which is an advantage of virtually marking the beam isocenter during CT simulation?
- A. Patient surface is acquired along with the marked isocenter point
 - B. Virtually marked isocenter point can be used as leveling mark
 - C. A three-point setup can be achieved
 - D. Treatment plan setup shifts can be eliminated

Key: D

Citations: Practical Radiation Oncology Physics, Dieterich S et al, 2016, Chapter 13, Elsevier, 1st edition.

Rationale: If a virtual marking system is used during CT simulation, it is possible to place the virtual point at the location of the target. In doing so, the marked point can be used as the beam isocenter and thereby eliminating the need to use setup shifts from the treatment planning system. This technique minimizes the possibility of shifting the patient in the wrong direction during setup and may reduce setup time.

244. What tumors have shown the shortest median latent period for radiation-induced malignancies?
- A. Breast
 - B. Leukemia
 - C. Lung
 - D. Brain

Key: B

Citations: EJ Hall and AM Giaccia. Radiobiology for the radiologist. 2012, 138-139. Lippincott, Williams and Wilkins.

Nakachi K, et al. Sixty years of follow-up of Hiroshima and Nagasaki survivors: Current progress in molecular epidemiology studies, Mutat Res, 659:109-117, 2008.

Rationale: Solid tumors do not appear for at least 10 years following irradiation, and often require several decades. Radiation-induced leukemias have a medium latent period of 8 years.

245. In the EORTC 22845 “non-believers trial” examining the use of early versus delayed radiation therapy for low grade gliomas, the use of early radiation therapy:
- A. improved quality of life but did not improve OS.
 - B. improved PFS but did not improve OS.
 - C. improved memory function but did not improve PFS.
 - D. improved nausea but did not improve PFS.

Key: B

Citations: Long-term efficacy of early versus delayed radiotherapy for low-grade astrocytoma and oligodendroglioma in adults: the EORTC 22845 randomised trial. Van den Bent MJ, Afra D, et al. 2005 Sep 17-23. 366(9490):985-90. Lancet.

Rationale: The EORTC 22845 trial randomized patients to radiation therapy of 54Gy vs observation. The median progression free survival was statistically different 5.3years vs 3.4years and the 5 year PFS was 55% vs 35%. However the median overall survival was not statistically different at 7.4 years vs 7.2 years.

246. What is the annual whole-body effective dose limit for a radiation worker?
- A. 0.05 Sv
 - B. 0.5 Sv
 - C. 5 Sv
 - D. 50 Sv

Key: A

Citations: Limitation of Exposure to Ionizing Radiation, NCRP 1993 Table 19. INCRP.

Rationale: The annual whole-body limit is 0.05 Sievert (5 rem) for a radiation worker.

247. A patient presents with a 1.5 cm p16-positive SCC of the left tonsil with 3 involved ipsilateral lymph nodes, all less than 6 cm in size. The AJCC-8 clinical stage is I. What is the MOST appropriate treatment?
- A. Radiation therapy alone
 - B. Neck dissection followed by radiation therapy
 - C. Radiation therapy and concurrent chemotherapy
 - D. Induction chemotherapy followed by radiation therapy

Key: C

Citations: NCCN Guidelines Head and Neck 2018 ORPHPV-3. NCCN 2.2018.

AJCC Cancer Staging Manual. O'Sullivan et al. 2017. 113-121. Springer 8th edition.

Rationale: The standard radiation-based management for a patient with oropharyngeal cancer and multiple involved ipsilateral lymph nodes is radiation therapy and concurrent chemotherapy. Even though the patient is Stage I by the AJCC-8 staging system, the treatment is based on the clinical features of multiple involved lymph nodes and the AJCC-7 staging system which is clinical T2N2b, Stage IVA. Induction chemotherapy is category 3 in NCCN.

248. For the atom oxygen, if the shell is M=3, how many orbital electrons are in that shell?
- A. 18
 - B. 3
 - C. 9
 - D. No such shell exists

Key: D

Citations: The physics of radiation therapy, Faiz M. Khan, 2010, 3, Lippincott Williams Wilkins, 4th edition.

Rationale: The maximum number of electrons in an orbit is $2n^2$, however, oxygen has only K and L shells. No M shell.

249. What did the EORTC H10 trial demonstrate among early stage Hodgkin lymphoma (HL) patients who received ABVD chemotherapy followed by a negative interval PET scan?
- A. Higher PFS with subsequent RT vs. chemotherapy alone among both favorable and unfavorable HL patients
 - B. Higher PFS with subsequent RT vs. chemotherapy alone among favorable but not unfavorable HL patients
 - C. Lower PFS with subsequent RT vs. chemotherapy alone among both favorable and unfavorable HL patients
 - D. Lower PFS with subsequent RT vs. chemotherapy alone among favorable but not unfavorable HL patients

Key: A

Citations: J Clin Oncol. Andre et al. 2017 Jun 13. 5(16):1786-1794.

Rationale: The EORTC H10 trial demonstrated increased incidence of relapse when radiation therapy is omitted following ABVD and a negative interval PET scan in both favorable and unfavorable HL subgroups.

250. Which cell surface marker expression acts as a “brake” on the immune system and prevents immune cell recognition of tumor?
- A. EGFR
 - B. PD-L1
 - C. CD-44
 - D. VCAM1

Key: C

Citations: Commun Integr Biol. Baaten et al. 2010. 508-512.

Rationale: EGFR is a growth factor receptor. PD-L1 is a transmembrane protein that plays a major role in suppressing the immune system. CD-44 is a cell surface glycoprotein involved in cell-cell interactions, cell adhesion, and migration. CD-44 participates in lymphocyte activation, recirculation, and homing. Integrins are cell surface heterodimers which play key roles in cell adhesion.

251. The PDD of a 6MV beam with a SSD of 100cm is 67.0%. If the SSD is changed to 110cm with an associated Mayneord F factor of 1.014, what is the PDD for the same field size and depth?
- A. 65.9%
 - B. 66.1%
 - C. 67.9%
 - D. 68.1%

Key: C

Citations: The Physics of Radiation Therapy, Khan, 2003, Chapter 9, Lippincott Williams Wilkins, 3rd edition.

Rationale: The change in PDD due to a change in SSD can be approximated using the Mayneord F factor. The relationship between the PDDs is noted as follows: $PDD2 = (F\text{-factor}) * PDD1$.

252. In the build-up region of a megavoltage photon beam, the ratio of the absorbed dose (D) to collision kerma (Kcol) is:
- A. < 1
 - B. 1
 - C. > 1
 - D. 0

Key: A

Citations: The physics of radiation therapy, Faiz M. Khan, 2010, 96, Lippincott Williams Wilkins, 4th edition.

Rationale: In the build-up region, the collision kerma is larger than the absorbed dose. At dmax, the collision kerma is roughly equal to the collision kerma. At depths past dmax, the absorbed dose is larger than the collision kerma.

253. If the linear attenuation coefficient of a mono-energetic x-ray beam in material X is 6.93 cm⁻¹, what is the half value layer (HVL) of material X for that beam?
- A. 0.1 cm
 - B. 1 cm
 - C. 6 cm
 - D. 10 cm

Key: A

Citations: The Physics of Radiation Therapy, Khan, 2010, 89, Lippincott, Williams Wilkins, 4th edition.

Rationale: The HVL is related to the linear attenuation coefficient μ by the following relationship: $HVL = \ln(2)/\mu \approx 0.693/\mu$

254. What BEST describes attenuation correction of a PET/CT study?
- A. Image processing correction to smooth the PET images
 - B. PET images corrected to account for signal differences due to various tissue types
 - C. A correction to account for CT x-rays detected in the PET detectors
 - D. A correction to account for PET detector response time during acquisition

Key: B

Citations: Practical Radiation Oncology Physics, Dieterich S et al, 2016, Chapter 14, Elsevier, 1st edition.

Rationale: Attenuation correction of PET images account for the detected signal due to various tissues types. For example, a lung lesion might be hyper intense due to less attenuation of the emitting radiation.

255. Per the RTOG 0631 spinal SRS trial, what is the spinal cord Dmax dose constraint for single fraction SRS?
- A. 10 Gy
 - B. 12 Gy
 - C. 14 Gy
 - D. 16 Gy

Key: C

Citations: Practical Radiation Oncology. Ryu, Samuel. 2014 March/April. 4 (2): 76–81.

Rationale: In RTOG 0631, the spinal cord constraint is a maximum dose (defined as a 0.03 cc volume) of less than 14 Gy and a V10 of less than 0.35 cc and a V10 of <10% (as defined by the cord volume 5-6 mm above and below the target).

256. Invasion of which structure, as shown in the image below, is a contraindication for laryngeal preservation in the treatment of laryngeal SCC?

- A. Strap muscles
- B. Thyroid cartilage
- C. Arytenoid cartilage
- D. Prevertebral muscles

Key: A

Citations: AJCC Cancer Staging Manual Patel, et al. 2017. 149-61 Springer 8th edition.
NCCN Guidelines Head and Neck. 2018. SUPRA-8.

Rationale: In the image laryngeal cancer can be seen extending into the strap muscles anterior to the cricoid cartilage. Invasion of the strap muscles establishes the stage as T4a which should be treated primarily with laryngectomy. Invasion THROUGH the thyroid cartilage would also be T4a disease, but the thyroid cartilage is not shown on the image. The arytenoid cartilages are not shown on the image. Invasion of the prevertebral muscles would indicate T4b disease, and would typically not be resectable. The prevertebral muscles are not involved in the image shown.

257. Involvement of which of these structures makes pancreatic cancer unresectable?

- A. Portal vein (<180 degrees)
- B. Inferior mesenteric artery (<180 degrees)
- C. Superior mesenteric vein (<180 degrees)
- D. Porta hepatic lymph node

Key: B

Citations: NCCN Guidelines Pancreatic Cancer. 2017 NCCN.

Rationale: The inferior mesenteric artery is outside of the region of the pancreas, and any involvement of the IMA would typically be considered metastatic.

258. What is the ocular salvage rate for Reese-Ellsworth stage IV – V retinoblastoma?
- A. 10-20%
 - B. 30-40%
 - C. 50-60%
 - D. 70-80%

Key: C

Citations: Friedman DL. 2017. Systemic neoadjuvant chemotherapy for Group B intraocular retinoblastoma (ARET0331): A report from the Children's Oncology Group. Wiley Periodicals. PMID: 28019092.

Levy C. 1998. Role of chemotherapy alone or in combination with hyperthermia in the primary treatment of intraocular retinoblastoma: preliminary results. 1154-8. BMJ Publishing Group PMID: 9924303.

Lucas JT Jr. 2018. Prior non-irradiative focal therapies do not compromise the efficacy of delayed episcleral plaque brachytherapy in retinoblastoma. BMJ Publishing Group PMID: 29954786.

Rationale: Patients with Reese-Ellsworth Stage IV-V retinoblastoma have ocular salvage rates of ~50-60%.

259. The use of which medications was monitored when evaluating the primary endpoint of the TIME-C (RTOG 1203) trial that compared adjuvant pelvic IMRT to 3D techniques in cervical and endometrial cancers?
- A. Urinary Analgesics
 - B. Anti-diarrheals
 - C. Anti-emetics
 - D. Silver Sulfadiazine

Key: B

Citations:

Ref 1 Page: Yeung AR, Pugh SL, Klopp AH, Gil KM, et al. Clinicians Underreport Adverse Events in NRG Oncology's Radiation Therapy Oncology Group 1203: The Importance of Using Patient-Reported Outcomes in Oncology Clinical Trials. 2016. Intl J Radiat Oncol Biol Phys S125.

Rationale: Patients with cervical and endometrial cancer who received pelvic radiation postoperatively were stratified by dose (45 or 50.4 Gy), use of chemotherapy (none or 5 cycles of weekly cisplatin at 40 mg/m²), and disease site, and then randomly assigned to standard 4-field radiation or IMRT. The primary endpoint was change in acute gastrointestinal (GI) toxicity from baseline to 5 weeks measured by the bowel domain of Expanded Prostate Cancer Index Composite (EPIC). 20.4% of women on the standard RT arm took 4 or more antidiarrheal medications daily, as compared to 7.8% of women on the IMRT arm (P Z 0.04).

260. Which feature is associated with increased risk of developing breast cancer?
- A. Atypical hyperplasia
 - B. Breast feeding
 - C. Exercise
 - D. Oophorectomy before age 45

Key: A

Citations: NCCN Breast Cancer Risk Reduction Guidelines, Version 2.2018.

Rationale: According to the NCCN Guidelines on breast cancer risk reduction, for a woman who does not have familial risk or genetic predisposition, atypical (ductal and lobular) hyperplasia is associated with increased risk. Prior oophorectomy before age 45 years, prior risk-reducing therapy, exercise, and breast feeding are associated with decreased risk.

261. According to the consensus statement from the International Radiosurgery Oncology Consortium for Kidney and primary renal cell carcinoma, what is a CONTRAINDICATION to renal SBRT?
- A. Hypertension
 - B. Prior high dose radiation therapy to the upper abdomen
 - C. Patient age > 60
 - D. Tumor size > 3cm

Key: B

Citations: Future Oncology. 12.

Rationale: SBRT is an emerging treatment modality in the management of renal cell carcinoma. Many of the same fundamental principles of SBRT for other disease sites, however, similarly apply.

262. On the NCIC MA-20 study of WBI +/- regional nodal irradiation, what grade 2 or higher treatment related toxicity was increased with regional nodal irradiation?
- A. Fatigue
 - B. Cardiac events
 - C. Neuropathy
 - D. Lymphedema

Key: D

Citations: Whelan TJ, Olivotto IA, Parulekar WR, et al., Regional Nodal Irradiation in Early-Stage Breast Cancer, *NEJM*, July 23, 2015, p. 314.

Rationale: There was no difference in the rates of grade 2 or higher fatigue, pain, neuropathy, or cardiac events between both groups (WBI +/- RNI). The risk of pneumonitis was 0.2% with WBI and 1.2% with the addition of RNI, $p=0.01$. The risk of grade 2 lymphedema was 4.5% in the breast alone group compared to 8.4% in the group receiving nodal irradiation with a p -value of 0.001.

263. According to the German Hodgkin Study Group, what is the stage of a Hodgkin lymphoma patient with involvement limited to the left cervical, supraclavicular, infraclavicular, and mediastinal lymph nodes?
- A. I
 - B. II
 - C. III
 - D. IV

Key: B

Rationale: Staging according to the German Hodgkin Study Group includes lymph nodes of the unilateral cervical, supraclavicular, and infraclavicular lymph nodes within the same nodal group while mediastinal lymph nodes would be a separate nodal group. Therefore, this patient would have two nodal groups involved and the clinical stage is II.

264. What is the recommended adjuvant treatment for locally advanced and/or node positive upper tract urothelial carcinoma in the post-operative setting?
- A. Close continued observation
 - B. Sequential radiation followed by chemotherapy
 - C. Cisplatin-based systemic chemotherapy
 - D. Concurrent carboplatin-based chemoradiation

Key: C

Citations: European Urology. 66(3).

Rationale: Though a rare disease, upper tract urothelial carcinoma (UTUC) often presents in advanced stages. Primary surgical resection is almost always recommended up-front, and in high risk disease, data from a recent meta-analysis showed a 57% overall survival benefit when adjuvant cisplatin-based chemo was given vs. surgery alone.

265. Local tumor irradiation improves T-cell recruitment and infiltration by reprogramming of the macrophages. What signaling molecule is secreted by macrophages to induce vascular normalization that allows the recruitment of T-cells?
- A. CXCL10
 - B. Nitric oxide
 - C. vascular adhesion molecule-1
 - D. CCXL16

Key: B

Citations: JAMA oncology. Demaria S., Golden EB., Formenti SC. 2015. 1325-1332.

Rationale: Local radiation therapy (RT) improves T-cell recruitment and infiltration into the tumor by reprogramming of the macrophages to secrete nitric oxide (NO) leading to vascular normalization. Enhanced tumor cell secretion of chemokines, such as CXCL10 and CXCL16, recruits CD8+ T cells (CTLs) to the tumor, and increased endothelial expression of vascular adhesion molecule-1 (VCAM-1) permits their extravasation. Once inside the tumor, radiation-induced upregulation of major histocompatibility class I (MHC-I), ICAM-1, Fas, and natural-killer group 2, member D (NKG2D) ligands on the cancer cells improves their recognition and killing by CTLs. NKG2D ligand upregulation also improves NK cell-mediated killing of cancer cells that have lost MHC-I expression.

266. The D10 for a population of tumor cells is 3 Gy and the extrapolation number $n=1$. What is the approximate single dose required to obtain a TCD90 for a tumor with 10 million clonogenic cells?

- A. 18 Gy
- B. 24 Gy
- C. 30 Gy
- D. 36 Gy

Key: B

Citations: Radiobiology for the radiologist Eric Hall, Amato Giaccia 2012, 38 Lippincott Williams and Wilkins 7th edition.

Rationale: To obtain a 90% probability of tumor control, on average, it would be required to reduce the number of tumor cells to 0.1. As the extrapolation number for the tumor cells is 1, it can be assumed that there is minimal or no “shoulder” for the survival curve. Therefore, for a population with 10^7 initial cells, the surviving fraction would need to be 10^{-8} , and could be achieved by $3 \text{ Gy} \times 8 \text{ logs} = 24 \text{ Gy}$.

267. Which of the following BEST describes DICOM®?

- A. A scheduling interface to coordinate acquisition and creation of medical images and related data
- B. A communication standard for transfer of medical images and related data
- C. A software package that analyzes medical images and related data
- D. A computer system that reconstructs medical images and related data

Key: B

Citations: Eur Radiol, Mildenerger, Eichelberg, Martin, 2002 Apr, 12(4):920-7.

Rationale: Digital Imaging and Communications in Medicine (DICOM) is an international standard supported by the National Electrical Manufacturers Association. Manufacturers that conform to the standard follow rules for data formatting and representation in their system designs. This allows data to be transferred and consistently interpreted among DICOM-compliant systems, including among those from different manufacturers or those with different purposes. Examples of DICOM-compliant transfers may be from a CT scanner to a picture archiving and communication system (PACS), or from a treatment planning system to a treatment delivery system.

268. According to the 15-year update of the EORTC 10853 trial of RT versus no RT following breast conserving surgery in DCIS, what was the relative reduction in any local recurrence with RT?
- A. By one quarter
 - B. By one third
 - C. By one half
 - D. By two thirds

Key: C

Citations: American College of Radiology Appropriateness Guidelines for DCIS, 2014.
Donker et al, JCO, 2013;31(32, p. 4054-9.

Rationale: While no differences were seen in breast cancer specific survival or overall survival in the 15-year update for the EORTC 10853 trial, the risk of local recurrence after radiation was reduced by 48%. The local recurrence free rate increased from 69% to 82%.

269. Based upon the DVH shown below for a postoperative EBRT plan for cervical cancer, what is the bladder V30%?
- A. 20%
 - B. 35%
 - C. 55%
 - D. 90%

Key: D

270. What adjuvant therapy is preferred for resected stage III sentinel node positive melanoma?
- A. Nivolumab
 - B. Ipilimumab
 - C. Interferon-alpha
 - D. Locoregional radiation

Key: A

Citations: Adjuvant Nivolumab versus Ipilimumab in Resected Stage III or IV Melanoma. Weber, et al. 2017. NEJM. 1824-35; 377(19).
NCCN Guidelines Melanoma 2018 ME-4.

Rationale: CheckMate 238 randomized resected stage IIIB, IIIC, or IV melanoma to either nivolumab or ipilimumab. 12-month recurrence-free survival was 70.5% for nivolumab and 60.8% for ipilimumab. The ipilimumab arm suffered greater toxicity. Ipilimumab and interferon-alpha may also be used by guidelines, but Nivolumab is preferred. Radiation may be considered in some cases of stage III melanoma with CLINICALLY positive lymph nodes.

271. A patient is being treated AP/PA using 6 MV beams to a central abdominal target. Setup imaging reveals weight loss has reduced the anterior-posterior separation by 2 cm. What is the approximate increase in dose to the target due to the weight loss?
- A. 3%
 - B. 6%
 - C. 9%
 - D. 12%

Key: B

Citations: Physics of Radiation Therapy, Khan, 2003, 60-63, 163, Lippincott Williams Wilkins, 3rd edition.

Rationale: For depths from 5-25 cm, a nominal 6 MV photon beam is attenuated by approximately 3% per centimeter. If the separation has reduced by 2 cm, then 1 cm of tissue is missing for both the AP and PA beams. The approximate increase in dose will be $2 \times (1 \text{ cm} \times 3\%/\text{cm}) = \sim 6\%$ in the centrally located target.

272. A patient has a cracked left upper 2nd molar that will require extraction prior to radiation treatment for oropharyngeal cancer. What is the number designation of this tooth per the Universal Numbering System used in the US?
- A. 6
 - B. 15
 - C. 24
 - D. 31

Key: B

Citations: Woelfel's Dental Anatomy. Scheid and Weiss. 2017, page 8. Wolters Kluwer 9th edition.

Rationale: The Universal Numbering System has been adopted by the American Dental Association and is the numbering system used most commonly in the United States. Tooth number 1 is the tooth farthest back on the right side of the mouth in the upper jaw. Numbering continues along the upper teeth to the tooth farthest back on the top left side (which is number 16). Number 17 is the tooth farthest back on the left side of the mouth on the bottom and number 32 is the tooth farthest back on the bottom right.

273. In a patient with cT3N2 squamous cell carcinoma of the anal canal, IMRT is justified by which of the following improved endpoints?
- A. Grade 3+ gastrointestinal toxicity
 - B. Grade 3+ hematologic toxicity
 - C. Local control
 - D. Overall survival

Key: A

Citations: Int J Radiation Oncol Biol Phys. 2013. Vol. 86, No. 1, pp. 27-33.

Rationale: On RTOG 0529, 5FU/mitomycin C was delivered with IMRT for anal cancer. The toxicity was compared to the historical control of the standard arm of RTOG 98-11. RTOG 0529 showed improved Grade 3+ GI toxicity (21% v 36%, $p=0.0082$), Grade 3+ dermatologic toxicity (23% v 49%, $p<0.0001$), and Grade 2+ hematologic toxicity (73% v 85%, $p=0.032$).

274. For radiation oncology IT data management, why is it essential to have a fall-back system in place in case there are unplanned outages of the record and verify system?
- A. The record and verify system verifies the accuracy of diagnosis.
 - B. The record and verify system drives the DICOM transfer of diagnostic images.
 - C. The record and verify system verifies the accuracy of the treatment plan.
 - D. The record and verify system drives the daily operation of treatments.

Key: D

Citations: Practical Radiation Oncology, Physics, Sonja Dieterich, 2016, 160, Elsevier, 1st edition.

Rationale: For the majority of patients, if the record and verify system goes down, treatment cannot take place. This is because the record and verify system controls the machine parameters for treatments. In some disease sites, extended treatment interruptions have been shown to negatively impact outcome. Therefore, it is critical to have a fall-back system in order to continue the operation of the record and verify system for treatment.

275. According to the 2018 ASTRO guideline update, what is a preferred dose fractionation schema for whole breast irradiation?
- A. 40 Gy in 15 fx
 - B. 42.5 Gy in 20 fx
 - C. 50 Gy in 25 fx
 - D. 50.4 Gy in 28 fx

Key: A

Citations: Smith et al., PRO, 2018: 8(3), 145-152.

Rationale: According to the recent ASTRO guideline update, the preferred dose fractionation scheme for whole breast radiation with or without the low axilla but without additional nodal fields is 40 Gy in 15 fractions or 42.5 Gy in 16 fractions. The guideline addresses whether various clinicopathologic factors affect this recommendation, the role for boost, and dose and treatment planning recommendations.

276. What are the common side effects of Cisplatin 100mg/m² used during concurrent chemoradiation for head and neck squamous cell carcinoma?
- A. Rash, hypomagnesemia
 - B. Myelosuppression, nephrotoxicity
 - C. Stomatitis, diarrhea
 - D. Alopecia, cardiomyopathy

Key: B

Citations: <http://www.micromedexsolutions.com> Truven Health Analytics Accessed 6/22/18.

Rationale: Common and serious side effects of cisplatin 100mg/m² include: nausea and vomiting, myelosuppression (25% to 30%), (nephrotoxicity 28% to 36%), ototoxicity and neuropathy. Cetuximab causes an acneiform rash and hypomagnesemia. 5-FU is known to cause stomatitis and diarrhea. Alopecia and cardiomyopathy are known to be associated with Adriamycin.

277. Why are cancer stem cells important targets of anti-cancer treatment?
- A. They repair normal tissue damage
 - B. They are resistant to therapy
 - C. They support the development of secondary cancers
 - D. They are responsible for radiation recall reactions

Key: B

Citations: Cancer stem cells and the ontogeny of lung cancer. Peacock CD, Watkins DN. *J Clin Oncol.* 2008 Jun 10; 26(17):2883-9.

Melanoma stem cells: the dark seed of melanoma. Zabierowski SE, Herlyn M. *J Clin Oncol.* 2008 Jun 10; 26(17):2890-4.

Rationale: Cancer stem cells are pluripotent cells with high replicative potential, resistance to therapy, and ability to repopulate an entire tumor through differentiation. They are thought to be responsible for metastases and may be increased in sites of metastatic disease.

278. According to AAPMTG 142, how often should an absolute dose output calibration be performed for a medical accelerator?
- A. Daily
 - B. Weekly
 - C. Quarterly
 - D. Annually

Key: D

Citations: Med Phys, Klein EE, et al., Sept 2009, 4197-4212.

Rationale: TG-142 recommends that absolute output be measured and calibrated using the TG-51 protocol to a $\pm 1\%$ accuracy on an annual basis. This requires an appropriate calibrated ionization chamber and measurement in liquid water with a strictly-defined geometry and process. Additionally, TG-142 recommends that output constancy, i.e. variation from a relative baseline, be checked both daily and monthly. Output constancy checks may be performed with a range of detectors and geometries. These tests are usually easier to setup and acquire the necessary data, but can only provide relative information about accelerator output rather than an absolute/calibrated dose value.

279. What is the most common histology of optic pathway gliomas in children?
- A. Pilocytic astrocytoma
 - B. Anaplastic astrocytoma
 - C. Ganglioglioma
 - D. Oligodendroglioma

Key: A

Citations: Jahraus Tarbell. *Pediatr Blood Cancer*. 2006, May 1; 46(5):586-96.

Rationale: Most optic pathway gliomas are low grade gliomas, most commonly pilocytic astrocytomas. Newly diagnosed patients should be evaluated for neurofibromatosis.

280. A tumor compressing the optic chiasm at midline but no other optic or neural structures would cause which visual abnormality?
- A. Monocular blindness
 - B. Homonymous hemianopsia
 - C. Diplopia
 - D. Bitemporal hemianopsia

Key: D

281. When using a thimble chamber to perform a water tank dose measurement, the majority of the ionizations produced in the air cavity are caused by:
- A. Electrons from irradiated water.
 - B. Electrons from chamber wall.
 - C. Electrons from the air in air cavity.
 - D. Electrons from central collecting electrode.

Key: B

Citations: The physics of radiation therapy, Faiz M. Khan, 2010, 72, Lippincott Williams Wilkins, 4th edition.

Rationale: From the basis of the Bragg-Gray cavity theory, the ionizations produced in the cavity air arise from electrons liberated in the chamber wall.

282. Regarding use of hypofractionation for PMRT:
- A. nearly half of patients on the START A and B trials received PMRT.
 - B. is associated with worse chest wall appearance and increased fibrosis versus conventional fractionation.
 - C. is contraindicated following autologous reconstruction.
 - D. the ongoing Alliance A221505 phase III PMRT trial compares 42.56 Gy in 16 fractions to 50 Gy in 25 fractions.

Key: D

Citations: Haviland et al, *Lancet Oncol*, 2013: 14, 1086-94.
Badiyan et al, *Radiotherapy and Oncology*, 2014: 110, 39-44.

Rationale: START A included 15% pts s/p mastectomy, START B had 8%; with 14% and 7% respectively receiving RNI. Worse chest wall appearance and fibrosis with hypofractionation have not been reported on prior trials using and will be further evaluated on the Alliance phase III RCT of hypofractionated PMRT (Alliance A221505: Hypofractionated radiation therapy after mastectomy in preventing recurrence in patients with stage IIa-IIIa breast cancer). This trial compares 42.56 Gy in 16 fractions with conventional fractionation and evaluates the rates of breast reconstruction complications, acute and late toxicities, and recurrence.

283. What method is utilized to evaluate the cumulative dose to the bladder using HDR brachytherapy for cervical cancer?
- A. Total prescribed dose converted using linear-quadratic model
 - B. The delivered fractional doses are summed then multiplied by 3
 - C. The delivered fractional doses are multiplied by 3 and then summed
 - D. The delivered fractional doses are converted using BED doses in 2 Gy equivalent and summed

Key: D

Citations: Brachytherapy. Viswanathan A 2012. 11(1), 47-52.

Rationale: To account for the biologic effect of hypofractionation used in HDR cervical brachytherapy, doses are usually converted to biologically equivalent doses in 2-Gy per fraction equivalents (EQD2) prior to adding them together. Alpha/beta ratio of 3 is commonly used for organs at risk.

284. Which lymph node station is LEAST likely to be involved in a clinical T3N0 hypopharynx squamous cell carcinoma?

- A. I
- B. II
- C. III
- D. IV

Key: A

Citations: Handbook of Evidence-Based Radiation Oncology, 3rd Ed. Hansen and Roach 2018 Springer International Publishing AG 3rd, Page: 210.

Distribution of cervical lymph node metastases from squamous cell carcinoma of the upper respiratory and digestive tracts. Lindberg 1972, 1446-9. Cancer 29(6).

Rationale: Hypopharyngeal tumors most commonly drain to levels II-V, as well as retropharyngeal and paratracheal lymph nodes areas.

285. A patient presents with an enlarging level Va cervical lymph node. What is the most likely primary site of disease?

- A. Oral cavity
- B. Oropharynx
- C. Larynx
- D. Nasopharynx

Key: D

Citations: Essentials of Clinical Radiation Oncology. Ward, Tendulkar and Videtic, Eds. 2018 page 114.

Rationale: Nasopharynx, skin of the posterior neck and scalp, and hypopharynx are the most likely locations of an unknown primary draining to level Va. Oral cavity would commonly drain to level I and II. Oropharynx and larynx would commonly drain to level II and III.

286. According to 2018 NCCN Guidelines, which newly diagnosed breast cancer patient does NOT meet criteria for further genetic risk assessment assuming no additional risk factors?
- A. 75-year-old female with triple negative breast cancer
 - B. 70-year-old female of Ashkenazi Jewish ancestry
 - C. 45-year-old female with DCIS
 - D. 55-year-old male with negative LNs

Key: A

Citations: NCCN guidelines, multiple, January 2018, BR/OV-1.

Rationale: A: Patients with triple negative breast cancer diagnosed at ≤ 60 years of age should be referred for genetic risk assessment.; B: Patients of Ashkenazi Jewish ancestry with a personal history of breast or high-grade prostate cancer should be sent for genetic risk assessment.; C: Patients diagnosed with breast cancer, invasive and DCIS, at ≤ 50 years of age should be sent for genetics risk assessment.; D: Male breast cancer patients should be sent for genetics risk assessment.

287. In which DNA repair pathway does DNA ligase IV primarily function?
- A. Non-homologous End Joining Repair
 - B. Homologous Recombination Repair
 - C. Base Excision Repair
 - D. Nucleotide Excision Repair

Key: A

Citations: The role of homologous recombination in radiation-induced double-strand break repair. Jeggo PA, Geuting V, Löbrich M. *Radiother Oncol.* 2011 Oct; 101(1):7-12.
Sensing and repairing DNA double strand breaks. Jackson SP. *Carcinogenesis* 2002 23: 687-696.
Regulation and mechanisms of mammalian double-strand break repair. Valerie K and Povirk LF. *Oncogene* 2008 22:5792-5812.

Rationale: There are two major types of DSB repair pathways in mammalian cells – homologous recombination repair (HRR) and non-homologous end-joining (NHEJ). A third type, single-strand annealing (SSA), shares components with both NHEJ and HRR. NHEJ uses little to no sequence homology in a process that may or may not be error-free. NHEJ requires fewer proteins than HRR, The NEHL proteins are Ku70/80, DNA-PKcs, DNA ligase IV, and XRCC4. HRR is dependent on DNA homology and is error-free. The requirement for sequence homology is the fundamental difference between HRR and NHEJ. It is generally believed that NHEJ plays a more important role than HRR in mitotically replicating cells while HRR may play a more prominent role when sister chromatids are available during late S and G2 stages of the cell cycle. NHEJ is more important during G1 and early S phase, while HRR operates in S and G2 due to the requirement for sequence homology.

288. DLBCL involving which site may predict a higher risk for CNS relapse, based on the German High Grade NHL Study Group?
- A. Lung
 - B. Heart
 - C. Bowel
 - D. Adrenal Gland

Key: D

Citations: Schmitz N, et al. 2013; 31 (Suppl 1: Abstract 047; Hematological Oncology.

Rationale: The German High-Grade Non-Hodgkin's Study Group proposed prognostic model to predict the risk of CNS relapse and incorporated the following 5 factors (age > 60, LDH > normal, stage III/IV, ECOG PS>1 and involvement of the kidney or adrenal gland). Rate of relapse at 2 yrs varied from less than or equal to 1% up to 17% with 4 or 5 factors. Thus, lumbar puncture should be considered in patients with 4-6 risk factors. Other risk factors also include greater than or equal to 2 extranodal sites, involvement of testes, paranasal sinuses, and bone marrow.

289. Chi square is zero when which of the following occurs?
- A. Expected frequency is less than the observed frequency
 - B. Expected frequency is equal to the observed frequency
 - C. Expected frequency is double that of the observed frequency
 - D. Expected frequency is triple that of the observed frequency

Key: B

Citations: Basic & Clinical Biostatistics, Saunders & Trapp, 1999, p. 150, Appleton & Lange, 2nd edition.

290. What is the minimum radiation dose for a patient with Stage I NK/T-cell Lymphoma for optimal outcomes?

- A. 24 Gy
- B. 36 Gy
- C. 40 Gy
- D. 50.4 Gy

Key: D

Citations: NCCN Clinical Practice Guidelines in Oncology, NCCN Guidelines-Non-Hodgkin Lymphoma Version 1.2018.

Rationale: Dose response over 50.4Gy has been demonstrated in many studies.

291. What is the actuarial incidence of scoliosis 15 years after 24 – 40 Gy for Wilms tumor?

- A. 14%
- B. 34%
- C. 54%
- D. 74%

Key: D

Citations: Paulino, et al. Int J Radiat Oncol Biol Phys., 2000, Mar 15; 46(5):1239-46.

Rationale: The incidence of scoliosis 15 years after radiotherapy for Wilms tumor was 20%, 49%, and 74% for patients treated with 10 – 12 Gy, 12 – 24 Gy, and 24 – 40 Gy, respectively.

292. The GEC-ESTRO MRI mandatory criteria for adaptive cervical cancer brachytherapy includes:
- A. Vaginal coil.
 - B. Rectal coil.
 - C. 3 mm slice thickness.
 - D. 5 mm slice thickness.

Key: C

Citations: Recommendations from Gynaecological (GYN) GEC-ESTRO Working Group (IV): Basic principles and parameters for MR imaging within the frame of image based adaptive cervix cancer brachytherapy. Dimopoulos, 2012, 113-122, Radiother Oncol, 103.

Image-Based Brachytherapy for the Treatment of Cervical Cancer, Harkenrider, 2015, 921-934, IJROBP, Vol 90, Number 4.

Rationale: Technical aspects of MRI-based brachytherapy.

293. For LINAC based SRS of a single, small spherical brain lesion, the use of IMRT over 3D conformal when using a large number of beams will:
- A. improve high dose conformity.
 - B. worsen high dose conformity.
 - C. have minimal impact on high dose conformity.
 - D. decrease integral dose.

Key: C

Citations: Practical Radiation Oncology Physics, Dieterich S et al, 2016, Ch. 16, Elsevier, 1st edition.

Rationale: Since the object is small and concave, the advantages of IMRT will be limited especially when looking at high dose conformity.

294. A 58-year-old patient with NSCLC presents with two asymptomatic, subcentimeter intracranial lesions consistent with brain metastases. Which radiotherapeutic strategy is MOST appropriate?
- A. WBRT with opposed laterals
 - B. WBRT with hippocampal avoidance
 - C. Stereotactic radiation
 - D. Neurosurgical resection with cavity radiation

Key: C

295. The depth of the Bragg peak in water for heavy charged particles depends largely on which factor?
- A. Particle spin
 - B. Particle magnetic polarity
 - C. Kinetic energy per nucleon
 - D. Particle rest mass energy

Key: C

Citations: The Physics of Radiation Therapy, Faiz M. Khan, 2010, 50, Lippincott Williams Wilkins, 4th edition.

Rationale: The kinetic energy per nucleon is also called specific kinetic energy, particle with the same specific kinetic energy will approximately possess the same velocity and range.

296. According to the AJCC 8th edition staging manual, a patient with a 3 cm p16-positive base of tongue SCC and a contralateral 4 cm lymph node is what stage?
- A. I
 - B. II
 - C. III
 - D. IVA

Key: B

Citations: AJCC Cancer Staging Manual. O'Sullivan et al. 2017. 113-121. Springer 8th edition.

Rationale: According to the former AJCC 7th edition, such a patient would be T2N2c, Stage IVA. The AJCC 8th edition modified the staging system to create prognostically accurate subgroups. Under the new staging system, such as a patient will be Stage II, with a clinical T-stage of T2 and clinical N-stage of N2 (contralateral or bilateral lymph nodes smaller than 6 cm).

297. A 5-year-old has a 4 cm embryonal rhabdomyosarcoma in his left thigh without lymph node involvement or distant disease. After biopsy and induction chemotherapy, the patient should receive what dose of focal radiation with concurrent chemotherapy?
- A. 36 Gy in 20 daily fractions
 - B. 41.4 Gy in 23 daily fractions
 - C. 50.4 Gy in 28 daily fractions
 - D. 59.4 Gy in 54 twice daily fractions

Key: C

Citations: Int J Radiation Oncology Biol. Phys. Donaldson SS, Meza J, Breneman JC, Crist WM, Laurie F, Qualman SJ, Wharam M 2001 Nov 15. 1(3):718-28

Rationale: As demonstrated on IRS-IV and other studies, Group III disease is treated to 50.4 Gy with concurrent chemotherapy. IRS-IV also failed to show a benefit for treat patients with hyperfractionation.

298. Which of the following photoelectron interactions contributes minimally to the total mass attenuation coefficient (μ/ρ) at therapeutic photon energies?
- A. Coherent
 - B. Photoelectric
 - C. Pair
 - D. Compton

Key: A

Citations: The Physics of Radiation Therapy, Khan, 2003, Chapter 5, Lippincott Williams Wilkins, 3rd edition.

Rationale: Coherent scattering is only important for very low photon energies and high Z materials. At therapeutic energies and in water equivalent medium, it is often omitted from the total mass attenuation coefficient.

299. What would be the effect on clonogenic survival if the time interval between the two 4-Gy fractions is decreased to 30 minutes from 4 hours?
- A. No change
 - B. Decrease
 - C. Increase
 - D. No survival

Key: B

Citations: Radiobiology for the Radiologist, Seventh ed. Hall and Giaccia, chapter 2, page 69.

Rationale: The repair time for mammalian cells in culture is typically 1-2 hours. Increasing fraction time from 30 minutes to 2 hours would increase surviving fraction in culture, especially if the cells are non-proliferative as there would not likely be a decrease due to reassortment. Cells can repair sublethal damage with normal p53 function. Lowering dose rate at 2 hours between fractions would not result in the same cell kill, as the higher dose rate at the 30 minute time point would both likely result in more cell death.

300. What is the risk of stroke 30 years after diagnosis among adult survivors of childhood cancer treated with at least 50 Gy cranial radiation?
- A. 2%
 - B. 12%
 - C. 22%
 - D. 32%

Key: B

Citations: Mueller, et al. Int J Radiat Oncol Biol Phys. 2013, Jul 15; 86(4):649-55.

Rationale: In a Childhood Cancer Survivor Study of 14,358 5-year survivors of childhood cancer, the risk of stroke after 50+ Gy cranial radiation was 1% at 10 years and 12% at 30 years. This risk is increased with risk factors for atherosclerosis.